AD A995152

12

POR-2004 (EX)
(WT-2004) (EX)
EXTRACTED VERSION

OPERATION DOMINIC

Shot SWORDFISH
Project Officers Report — Project 2.1
RADIOLOGICAL EFFECTS FROM AN UNDERWATER NUCLEAR EXPLOSION (U)

U.S. Naval Radiological Defense Laboratory
San Francisco, California

June 14, 1963

NOTICE

This is an extract of POR-2004, Operation DOMINIC, which remains classified SECRET/RESTRICTED DATA as of this date.

Extract version prepared for:

Director
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

1 November 1981

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
POR-2004 (WT-2004) (EX)

2. GOVT ACCESSION NO.
AD-A995152

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Operation DOMINIC - Shot SWORD FISH - Project Officers Report - Project 2.1 - Radiological Effects From an Underwater Nuclear Explosion (U)

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER
POR-2004 (WT-2004) (EX)

7. AUTHOR(s)
Lansing E. Egeberg
Lyle D. Johnson
Neil H. Farlow

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Naval Radiological Defense Laboratory
San Francisco, California

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Chief, Defense Atomic Support Agency
Washington, D. C.

12. REPORT DATE
June 14, 1963

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; unlimited distribution.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
This report has had the classified information removed and has been republished in unclassified form for public release. This work was performed by Kaman Tempo under contract DNA001-79-C-0455 with the close cooperation of the Classification Management Division of the Defense Nuclear Agency.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Operation DOMINIC
Shot SWORD FISH
Radiological Effects
Underwater Nuclear Explosion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The surface gamma radiation fields resulting from the burst of an antisubmarine rocket (ASROC) with a nuclear warhead were measured at a limited number of stations. In addition, measurements were made and samples collected in order to study base surge physical and radiochemical characteristics. Early-time surface water samples of the residual radioactivity in the ocean about surface zero were collected for the radiochemical determination of the yield of the weapon.

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE UNCLASSIFIED

FOREWORD

This report has had classified material removed in order to make the information available on an unclassified, open publication basis, to any interested parties. This effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is all currently classified as Restricted Data or Formerly Restricted Data under the provision of the Atomic Energy Act of 1954, (as amended) or is National Security Information.

This report has been reproduced directly from available copies of the original material. The locations from which material has been deleted is generally obvious by the spacings and "holes" in the text. Thus the context of the material deleted is identified to assist the reader in the determination of whether the deleted information is germane to his study.

It is the belief of the individuals who have participated in preparing this report by deleting the classified material and of the Defense Nuclear Agency that the report accurately portrays the contents of the original and that the deleted material is of little or no significance to studies into the amounts or types of radiation received by any individuals during the atmospheric nuclear test program.

* Per: telecon w/Betty Fox, Chief, DNA Tech Libr'y. Div.: the Classifed References contained herein may remain.
5 Sept.'79
Vic LaChance
DDA-2

**Verified for Extracted Versions.
9 July'80
pfcooper, DTIC/DDA-2

ABSTRACT

The surface gamma radiation fields resulting from the burst of an antisubmarine rocket (ASROC) with a nuclear warhead were measured at a limited number of stations. In addition, measurements were made and samples collected in order to study base surge physical and radiochemical characteristics. Early-time surface water samples of the residual radioactivity in the ocean about surface zero were collected for the radiochemical determination of the yield of the weapon.

The array consisted of eight stations extending from 7,500 feet upwind to 14,700 feet downwind from surface zero. The surface wind was at an angle of approximately 40 degrees to the axis of the array.

The base surge and the contaminated water patch were the predominant sources of gamma radiation generated by the detonation of the weapon. Within 5 minutes in a 10-knot surface wind, the base surge expanded radially from surface zero to 6,500 feet upwind, 7,500 feet crosswind, and 14,000 feet downwind. By the end of that time, maximum upwind and crosswind extent had been reached, and the entire mass of the surge was carried downwind. Within the first 10 minutes, dose-rate levels of from 300 to 4,000 r/hr were recorded within the base surge with 100 r/hr being recorded at the edge of the surge as late as H + 20 minutes. The dose-rate gradient from the surge in the upwind direction was very steep, with 90 percent of the total dose to all upwind stations outside of the surge being delivered in the first 10 minutes after the detonation. The deposit dose from the surge was not significant. The dose contribution by the surge to all stations was either from shine or from the passage of the surge over the station or both.

The radioactive water patch formed by the detonation expanded radially from surface zero to form a roughly circular contaminated area on the surface of the water about 14,000 feet in diameter at the end of the first hour. At that time, gamma dose-rates of from 2,500 to 6,000 r/hr were recorded within the limits of the patch. Peak dose rates as high as 17,000 r/hr were recorded within the patch at H + 17 minutes and 100 r/hr as late as H + 3 hours.

The yield of the weapon was independently determined from radiochemical analysis of samples taken from the contaminated water patch and quantitative knowledge of the device's original

contitutents. The results indicated a yield of

Postshot radiological monitoring of all stations showed that those stations within the water patch were contaminated with an alpha emitter identified as Pu^{239}. The contamination was concentrated at the waterline of the station, indicating that at least the surface of the water patch contained a significant amount of this material. Postshot monitoring showed no significant alpha or gamma contamination of the salt water systems operating on the vessel which collected the water samples from the contaminated water patch. The normal steaming operations of the vessel served as an effective decontamination procedure.

The USS Bausell (DD-845) located 6,400 feet upwind of surface zero, received its total gamma dose in the first 10 minutes of the event. Gamma dose-rates and total dose at below-deck locations was reduced by as much as a factor of 100 by the natural shielding afforded those locations by the structure of the ship. The three weatherdeck locations for which there were records show no such reduction.

A table of the total gamma dose versus station location is given below with notes indicating the sources from which the dose was accumulated.

Station	Distance from SZ (ft)	Total Gamma Dose (r)	Time to 90% Total Gamma Dose (min)
1 - Upwind (a)	7,250	.375	7
2 - Upwind (a)	5,170	22.	12.5
3 - Upwind (b)	3,980	923.	19
4 - Downwind (b) *	2,430	4,250.	46
5 - Downwind (b)	3,590	207.5	16
6 - Downwind (b)	6,890	344.	6
7 - Downwind (c)	10,340	38.5	10
8 - Downwind (c)	14,790	20.	17.5
Bausell (a)	6,400	2.1	10.5

(a) Shine from plume and surge only.
(b) Surge and water patch.
(c) Surge only.
(*) This station capsized at about H + 50 seconds.

PREFACE

Shot Sword Fish was an underwater weapon-effects test conducted in the Pacific Ocean off the southwest coast of the United States on 11 May 1962 as part of Operation Dominic. Sword Fish was also the first fully operational test of the Navy's antisubmarine rocket (ASROC) weapon system in which a nuclear war reserve weapon was expended. Radiological weapon-effects information of importance to the advancement of surface ship capability to conduct nuclear antisubmarine warfare was obtained.

This report supersedes the Project Officer's Interim Report (POIR-2004) "Radiological Effects from an ASROC Delivered Weapon", July 1962. It also supersedes the information abstracted from the above report which appears in the Scientific Director Summary Report, for Shot Sword Fish of Operation Dominic, dated July 1962.

The writing of a report of this nature limits the authorship to a very few people. Yet the material out of which the report is written is generated by a large number of people who served anonymously. Enforced brevity precludes full recognition of all of these contributors. The authors are nonetheless aware of this support and express their gratitude. A list of the principal contributors follows.

Special thanks are extended by the authors to the officers and crew of the USS Sioux (ATF-75), for their part in the sampling and the radiological survey of the water patch.

Thanks is also extended to Dr. Nathan Ballou of NRDL and particularly to Leland R. Bunney and his group, who performed the radiochemical yield determination.

For radiological safety consultation and advice, Albert L. Baietti and Edward J. Leahy.

For military liaison, CDR Thomas L. Birch, USN.

For superior performance as staff assistant to the Project Officer, Louis B. Gomez, YNC, USN.

For instrument maintenance, installation and recovery, Byron J. Hansen, Andrew L. Berto, James A. Reichardt, and Edmond W. Jones.

CONTENTS

TABLES

FIGURES

Chapter 1

INTRODUCTION

The radiological environment created by the detonation of an antisubmarine rocket (ASROC) depth charge is the principle factor governing the formation of attack strategy and subsequent maneuvering tactics involved in the delivery of that weapon.

The establishment of delivery stand-off distance based on shock as well as radiological considerations, is important but is involved only at the start of an attack problem. The radiological aspects are continuing however. They must be considered throughout the entire evolution of the attack situation and are compounded by successive attacks in the same area. Immediately following an attack, the delivery vessel must re-establish contact with the target for purposes of kill confirmation or further pressing of the attack, either on the same or additional targets. It is therefore necessary that the general nature of the radiological environment created be known in advance in order that proper strategy can be preformulated for varying attack situation.

Since the base surge is known to be a predominant source of radiological effects, theoretical studies and operational analyses of underwater detonations have been based primarily on data from the base surge and cloud originating from high-explosive model work and the results of Operations Crossroads, Wigwam, and Hardtack (References 1 through 3). These analyses have suffered from uncertainties in the relationship between the above-surface effects and the related distribution of radioactivity; from geometric simplification of the base surge and cloud required for mathematical treatment; and from the assumption of no fission product fractionation in the base surge. It is evident that more empirical data on these effects is required to further evaluate the radiological environment and its military implications for the general case of the underwater nuclear detonation. Of even more importance is the acquiring of specific data applicable directly to the ASROC depth charge in view of its present operational status in the fleet. Accordingly, this Project was designed to collect input data for a more precise description of the environment resulting from the detonation of that weapon, scheduled as Shot Sword Fish of Operation Dominic.

1.1 OBJECTIVES

The general purpose of the Project was two-fold: to obtain data which could be translated directly into a description of the radiological environment created by the detonation of the ASROC weapon for immediate application to the operational use of that weapon; and to secure data for a better theoretical understanding of the radiological aspects of all underwater nuclear bursts. Several factors, notably the lack of sufficient preparation time and the nature of the Task Group Operation Plan, made a large-scale project impractical. The effort was therefore restricted to the following specific objectives.

1.1.1 Surface Gamma Radiation Measurements. These were the measurements of prime importance to the Project, and a major portion of the effort expended was in behalf of these data. The recording of the gamma fields were planned at eight floating stations, some upwind and some downwind from surface zero, on a line parallel with the direction of the wind. The station locations were established to allow the best possible separation of the gamma dose from the plume, base surge, and contaminated water patch. This placed some upwind stations beyond direct contamination by the base surge and yet close enough to record the gamma field created by it. It also placed both upwind and downwind stations within the limits of both the surge and contaminated water patch. Finally, it placed some downwind stations outside of the water patch but still within the limits of the wind-driven base surge.

It was hoped that, by the use of photographic coverage, the location of all stations could be determined with respect to time, surface zero, and the visible surface effects from the detonation. With this information, the best possible picture of the event could be deduced when correlated with the records of the gamma fields with respect to time.

This was accomplished by use of a Gamma-Intensity-Time-Recorder at all stations and the photographic coverage supplied by Project 1.2 from the Naval Ordnance Laboratory at White Oaks, Maryland (NOL). T he product of these data would establish total gamma dose at station locations, dose rate with respect to time at those locations, and permit the separation, where permissible, of the various contributing sources to the total gamma field.

It was realized at the outset that the application of data from so few stations to the accurate description of the event would be limited. Due to the necessity for the single line array and the consequent lack of station density, the data obtained from each station would be explicit only for the location of that station. However, continuity of data from the several stations would imply similar conditions for geometrically similar locations in the area. Separation of the contributions of the various sources of gamma radiation such as the contaminated water patch and the base surge could be made only in the absence of all other contributors because of the omnidirectional response of the gamma recording instrument used. Because of these limiting circumstances, the overall picture of the event as formed from the data gathered was implicitly drawn, interpreting the data in the light of known site conditions and the symmetry of the visual above surface effects.

1.1.2 Radiochemical Yield Determination. The radiochemical yield of the weapon was determined as a separate task, not necessarily connected with or related to the rest of the data. The independent determination of the yield was necessary to the operation, since practically all data and measurements made by all of the projects were corollary to it. From an operational standpoint, the Project's objective was to secure proper samples from which the determination could be made and to arrange for the delivery of the samples to NRDL in the shortest possible time. In order to obtain samples of sufficiently high specific activity (10^{12} fissions/liter or more) the earliest entry into the patch was planned. Fast air transportation direct from the shot site to NRDL assured prompt delivery of the samples.

The actual yield determination was performed at NRDL with the assistance of outside contractors on the routine radiochemistry. The results will be reported separately and in detail at a future date. It is intended in this report only to give a brief description of the approach used, the resultant yield, and a statement as to its accuracy.

1.1.3 Target Vessel Gamma Fields. Gamma field measurements were made at selected locations aboard the USS Bausell which was a FRAM-1 conversion of a Gearing class destroyer, fitted with the ASROC depth charge delivery system and located in the towed array 6,500 feet from surface zero in a simulated weapon delivery position. From these measurements, a qualitative evaluation of the natural shielding afforded the crew of such a vessel by the structure of the vessel itself could be made when combined with the information regarding the gamma fields in the vicinity of the vessel as given by the floating stations.

1.1.4 Base Surge Measurements and Sampling. To gain further insight into the mechanisms of the surge's physical and radiological makeup, sampling of the gas and water phase of the surge was undertaken. In addition, measurements of the droplet count of the larger droplets (0.55 to 4.00 mm) present in the cloud were attempted. These measurements and samples were aimed at supplying input data for a base surge model theory now under development at NRDL. This theory is based on a droplet coalescence principle as a basis for describing the physical characteristics of the base surge (Reference 4). When combined with the proposed radionuclide fractionation theory of the base surge as put forth by P.D. La Riviere, the model will have the capability of predicting the amounts of certain radionuclides distributed in the cloud and rainout drops, for a number of yields and depths of burst under normal weather conditions.

The droplet count data was planned for deriving input conditions for this model. In addition, radiochemical analysis of the samples for Ba^{140} and La^{140} would serve to establish the extent of radionuclide fractionation within the base surge cloud. Decays of the samples taken from the radioactive water patch were planned as a further qualitative check on the extent of the fractionation that took place.

1.2 BACKGROUND

Past nuclear test series have included four underwater detonations as presented in Table 1.1. Measurements of the visible above-surface phenomena and radiological history were made to some extent on all of these events. The most complete radiological data came from the Project 2.3 coverage of the and Umbrella events (Reference 3).

1.2.1 Event Description. Because of the close similarity between the and Sword Fish events in yield and depth of burst, the former event was used almost exclusively for the planning of the Sword Fish station array. It was assumed that the above-surface visual and radiological effects would be comparable. From the experience gained from the previous tests, particularly the Wahoo experience, the radiological environment was considered to consist of three major sources of gamma dose rate. These were the plumes, the base surge, and the contaminated water patch. The gamma dose delivered by these sources came either from shine extending beyond the physical limits of the source or from direct contact with the source. Of these sources, direct contact with either the surge or the water patch appeared to be the most important due to their persistence in time and the corresponding high total gamma doses which could thereby be accumulated.

There were also minor contributors of dose rate from radioactive material deposited directly by the passage of the base surge and radioactive material picked up by vessels and stations from the water patch.

Chronologically, the plume is the first source of gamma radiation at the surface. It is radioactive and is thrown upward to a height of at least 1,700 feet for this yield and burst depth. Because of the limited time this source exists (about 30 seconds), its dose contribution to any station is small when compared with the dose from the surge. It is probable that vessels located at sufficient distance upwind from surface zero to maintain mobility after the passage of the underwater shock wave would be far enough removed to render minor the total gamma dose from the plume.

As the plume subsides, the base surge forms and rapidly expands radially outward from surface zero. The water and mist contained in the base surge is also highly radioactive, receiving its energy of motion from the subsiding plume. The contribution by the shine from the surge is not known. It was shown from the Wahoo experience, however, that the dose rates within the base surge are in the range of thousands of roentgen per hour and that total gamma dose in such locations can be correspondingly high from an operational standpoint even though the time that the location is exposed to radiation from the base surge is relatively short. Though the base surge is visible for about 10 minutes after the detonation, it remains as a radiation source for a much longer time. The length of time that it remains in the burst area depends upon the velocity of the surface wind; it remains longest in a no-wind condition. Thus, the base surge is known to be a dangerous source of gamma radiation over an operationally large downwind area and for a considerable length of time after the burst of the weapon. The area is defined primarily by the extent of the surge growth during the first 5 minutes and the surface wind velocity.

During the initial stages of the base surge formation, or perhaps even before that time, the water patch forms and spreads out radially from surface zero. Its rate of growth is slower than that of the surge, and its ultimate size within the first hour is not as large. The water contained in this patch is known to be highly radioactive and is made visible initially by large expanses of white foam which cover its entire area. The patch grows in size to 2 miles or more in diameter within the first hour. By that time, the foam has all but disappeared, leaving the patch invisible to the eye. Information as to the gamma fields existing within the water patch at this time have been measured at previous nuclear tests in only isolated cases, not necessarily applicable to the patch left by the ASROC weapon. Certainly, for bursts taking place in deep water where the bottom of the ocean is not involved, the gamma fields created by the water patch present a possible serious hazard to ship operation in the area of the burst for a significant length of time. In contrast, Umbrella data indicated a scavenging of fission products by bottom material which reduced the patch gamma field. In any event, due to its initial high dose rate and its persistence in time, the water patch must be considered as a major source of gamma radiation, at least within its geographical limits.

<u>1.2.2 Highlights of Nuclear Test Results</u>. The results of past nuclear underwater tests, principally those events covered by Reference 2, have shown that safe standoff delivery distance of a nuclear depth charge is controlled in some cases by the total gamma dose received by the delivery vessel. The predominance of the transit dose over both the deposit dose from the base surge and the shine from the plume

and surge is also shown in these results. Data were obtained which for specific conditions allowed rough predictions of the transit dose-rate history to be made. However, knowledge of the base surge formation processes and of how the total dose from all sources is received is still limited. For this reason, predictions of safe standoff distance and formation of attack strategy over an extended range of shot yields and depths have low levels of confidence.

Because of the 1958 nuclear test ban, NRDL expanded the Hydra Program (Reference 5) to continue the studies of the various processes resulting from an underwater detonation, which influence the overall distribution of radioactive debris. The field phase of this program was based on the use of large high-explosive charges as model detonations with incorporated radioactive tracers. These studies to date have been limited to shallow explosions. Much of the input data used in the development of the droplet coalescence model was obtained from this work, but since its development antedates the last nuclear testing, no full-scale input data has been available for its testing. The base surge measurements taken by the Project were designed to fulfill this need.

Other models have been developed at NRDL (Reference 6 and 7) for computing base surge dose-rate histories for underwater bursts. They assume simple geometric shapes to represent the base surge for varying yields, depths of burst, and wind conditions. They also assume varying percentages of the total fission products uniformly distributed in the surge, with no fractionation of the products taking place. These assumptions were necessary because information was insufficient for evaluating additional pertinent variables. The geometry of the time-dependent dimensions of the base surge for each of the past underwater nuclear shots were fed into the model, and by employing various concentrations of radioactivity in the surge, fair agreement with measured dose rates was obtained. The final values for the assumptions were chosen so that they produced the best fit with the measured results; thus, the validity of the model has been positively indicated only for those shot geometries from which its input data were obtained. In Reference 7, a need is expressed for further data and study to increase the model's reliability and range of application.

TABLE 1.1 PREVIOUS SHOT DATA

Operation	Shot	Nominal Yield (kt)	Burst Depth (ft)	Water Depth (ft)
Crossroads	Baker	23.5	90	180
Wigwam	- -	30	2,000	Deep
Hardtack	Wahoo		500	Deep
Hardtack	Umbrella		Bottom	148

Chapter 2

PROCEDURE

2.1 PARTICIPATION

Unlike the major portion of the Dominic Operation, which was carried out from Central Pacific Ocean Islands, Sword Fish was staged out of the Naval Repair Facility at San Diego, California. The shot site was located over the Jasper Seamount about 400 miles west and slightly south of that city. The shot was fired on 11 May 1962. General information regarding site conditions at the time are shown in Table 2.1.

Participation of Project 2.1 in this test involved the taking of radiological weapons-effects measurements. The instrumented station array consisted of a tow line approximately six miles long. The tow was made up of a vessel (USS Bausell), eight coracle stations, a raft which was actual target of the weapon, and an end-of-tow raft (See Figure 2.1).

The Bausell (DD-845) proceeded to the test site under her own power. The coracle stations were transported on the flight deck of the USS Monticello (LSD-35) from which they were launched and attached to the towline. The towed array was assembled on the morning of shot day and was taken in tow by the USS Molala (ATF-106) in a generally upwind direction.

All coracle stations, numbered 1 thru 8, were equipped with the following instruments. Two Gamma-Intensity-Time-Recorders (GITR) were installed to record the gamma fields throughout the event. They were identical and were used in duplicate to safeguard the loss of data due to possible instrument failure. Physical measurements of the base surge were made with the Automatic Droplet Counter (ADC) designed to establish relative quantities of four of the larger droplet sizes expected within the surge. A gas-fraction sampler and water-fraction sampler for collecting those phases of the surge completed the instrument complement of the station.

GITRs were also placed at 13 locations on the weather decks and below decks aboard the Bausell to record the gamma fields.

During preparation in the staging area, instruments were checked out and installed, array streaming rehearsals were conducted by the task force, and methods perfected for station handling. All major project work was completed at the staging area with only the arming of stations left for the sea operation.

Station arming started on May 9, and on May 10, the scheduled shot day, the stations were launched and the entire array assembled. On the first attempt to fire the shot, trouble developed on the firing ship, causing a one-day delay. This made it necessary to disassemble the entire array. The following day, May 11, stations were rearmed and the array reassembled.

The shot was fired at about 1300 PDST, and by early morning of D ≠ 1 day all stations had been recovered. Late in the afternoon of the shot day, the yield samples, taken by the project from the contaminated water patch, were transferred from the sampling vessel to an aircraft carrier from which they were flown directly from shot site to NRDL for analysis. All other samples and data tapes were recovered on D ≠ 1 and returned to NRDL for processing as soon as the ships returned to the staging area.

2.2 INSTRUMENTATION

The Project was fortunate in having the GITRs on hand from the start of planning. The coracles also were available and were made ready with only minor repairs and internal instrument arrangements. These two items had been used with considerable success by NRDL during the HARDTACK Operation. Their availability made it possible for the project to execute its objectives with relatively short lead preparation time and at a very low instrument cost. Without them, the Project could never have fielded the effort with the sophistication which these items represented.

<u>2.2.1 Instrument Stations</u>. The coracle used by the Project was a round fiberglass buoy made up of three major parts: the hull, the top, and the instrument well. Springs

suspended the top and its instrument well from the hull. This arrangement was capable of reducing a shock loading of 200 g at the hull to 5 g in the instrument well. Figures 2.2 and 2.3 show the general arrangement of the coracles as well as some of the construction details. Complete information on the hull geometry can be found in Reference 3.

2.2.2 Gamma-Intensity-Time-Recorder. The primary instrument used by the project was a portable, self-contained, gamma-intensity-time recorder. It was also the primary instrument for Project 2.3, Operation Hardtack, and its discription is fully covered in References 3 and 11. Briefly, it is 16 by 13 by 21 inches high, weighs about 55 pounds with power supply, and consists of these units: a radiation detector with time base, a three-channel recording system, a battery pack, and miscellaneous instrument control switches and associated circuitry.

The detector unit can be mounted either inside the recorder case or as a separate cable-connected unit. The GITR was used with both detector configurations on this operation. The sensitive element is a low-range ionization chamber containing a concentric, internally mounted, high-range chamber. The common base of these chambers contained the associated recycling electrometer circuits.

Both chambers have a nearly 4-pi response and are independent of incident gamma energy within ± 20 percent from 100 kev to 1.3 Mev. The discharge of either chamber fires its associated electrometer, giving a square-wave pulse which is amplified and recorded on magnetic tape. The transducer automatically recycles to the origin [illegible] charge condition in about 0.5 msec. Each recorded pulse represents an increment of gamma dose which, by means of time pulses, can be converted to dose rate. The dose increments from the two chambers and the time base are recorded as three channels of information on a ¼-inch magnetic tape. The tape transport has a tape speed of 0.25 in/sec, giving 12 hours of operation with a range of 10 mr/hr to 10^5 r/hr. The timing pulses were accurate to ± 0.10 percent.

Each coracle contained two identical GITRs with remotely located detector heads housed in watertight 14-gage aluminum shells mounted on the coracle deck (see Figures 2.2 through 2.4).

Eleven GITRs were placed on the weather decks and in selected compartments of the Bausell. Shipboard GITRs were arranged with the detector head mounted inside the case. The case was mounted in a shock frame (see Figure 2.5) welded to the ship's deck. Locations of the GITRs on the Bausell are shown in Figure 2.6.

2.2.3 Automatic Droplet Counter. The automatic droplet counter was a modified GITR. The GITR ion chamber head was replaced with a droplet size sensor. This sensor (see Figure 2.7) contained four pairs of wires across an opening, the wires in each pair being 0.5, 1.0, 2.0 and 4.0 mm apart, in air. The distance between the pairs was far in excess of the largest stable droplet size. These wires were mounted in a rigid head, and the head was mounted on the coracle 18 inches above the deck, with the plane of the wire pairs at 45 degrees to the deck (see Figure 2.2).

As the droplets passed through the plane of the wires, they shorted out wire pairs momentarily, depending on the drop size and the wire pair dimension. The shorting of any wire pair fired its associated electrometer, giving a square-wave pulse which was recorded on the magnetic tape. Since each GITR tape transport contained three channels, the use of four wire pairs necessitated two modified GITRs for each station, giving a total of four data channels and two timing channels.

2.2.4 Gas Fraction Sampler. The gas fraction sampler was designed to extract a sample of gas from the base surge as it passed over the station. The water phase of the surge was filtered out at the entrance surface of the collecting head. The instrument (see Figure 2.8) consisted of two tanks mounted one on top of the other. A filter head was located in the sample intake pipe above the deck of the coracle, and a valve was between the two tanks. The top tank was charged with water, and when the valve between the tanks was opened, the water passed from top to bottom, drawing a gas sample into the top tank. The valve, located between the two tanks was a glass globe with an explosive squib inside. The globe was broken by the squib which was detonated by a radiation trigger. (see Section 2.2.6).

2.2.5 Water-Fraction Collector. The function of the water-fraction collector was to collect samples of the rainout from the plume and base surge. It consisted of a bottle and funnel connected by a tube. The funnel was located 18 inches above the coracle deck. The bottle was inside the instrument well.

2.2.6 Instrument Control and Timing Fiducials. Control of instrument timing and starting was accomplished within the Project. The GITRs and ADCs were started at the time the stations were placed in the array. The gas fraction samplers were to have started by a special radiation trigger. Time was established either from a fiducial mark placed on the recorder tapes at starting time or by a pressure transducer activated by the pressure wave from the detonation of the weapon.

The GITRs and ADCs were started just prior to being placed in the array. A rated chronometer set to Greenwich Civil Time (GCT) was used as standard Project time. Fiducial marks were placed on the recorder tapes immediately after instrument starting and the time logged from a rated comparing watch.

Each coracle station and the Bausell were equipped with a pressure transducer that placed a signature on all GITR tapes, all ADC tapes, and all GITR tapes on the weather deck of the Bausell, at the time of arrival of the shock wave. Detonation time was established by the Task Force. The initial manually placed timing fiducial, along with the shock wave signature and the time of detonation, allowed real time to be established on the recorder tapes within the $\pm$ 0.10-percent accuracy of the timing marks placed on the tapes by the recorders.

The Gas-Fraction-Sampler was required to sample for two minutes immediately after a dose rate of from 40 to 50 r/hr was reached at the station. A radiation trigger was used to initiate the sampling operation. The trigger was built up from a commercially available survey radiac meter. The output of the meter was disconnected from the 5 μa meter movement and was used to trigger a thyratron. When the dose rate rose to the required level, the thyratron fired, closing a relay which in turn put a dry cell across the squib in the valve between the sampler tanks. Simultaneous with the triggering, a timing mark was placed on the recorder tapes, allowing time of the sampling to be established.

2.2.7 NRDL GITR Tape Readout. The GITR readout was an electronic device developed at NRDL to convert data pulses recorded on GITR tapes into raw data, the character of which depended upon the type of sensor head used. In this instance, the data represented gamma dose per unit time using the ion chamber head, and number of pulses from the wire pairs per unit time using the droplet head.

The main components of the system are shown in Figure 2.9. The system operated in the following manner. The tapes were run on the tape transport. The timing channel was amplified and sent directly to the decade scaler, where it was accumulated. The selected data channel was fed through an amplifier and modifier to the electronic counter. The timing channel was also fed into the counter and gated such that the data between every other timing mark was counted and accumulated in the storage unit. At the end of every other timing mark, the storage unit printed out its accumulated data on the digital recorder, along with the total accumulated from the decade scaler. Where the amount of data per unit time was low, the system was altered to gate the counter on data pulses rather than timing marks. This printed-out data was then in terms of time per unit of data.

2.3 OPERATIONS

Operations were divided into three time phases. They started with the arrival of the project at the staging area; then moved aboard ship for the operations at the site of the shot; then returned to the staging area and to NRDL for the roll-up of the equipment and analysis of the data. Three weeks before the shot day, the Project moved to the Naval Repair Facility (NRF) at San Diego where a work and storage area was set up and preshot preparations were accomplished. Sea operations lasted seven days followed by a return to San Diego for the rollup of the Project and preliminary data reduction.

2.3.1 Staging Area Operations. During the three-week period at NRF prior to embarking for the shot site, all instruments were bench-checked and installed in the coracles.

GITRs were checked for triggering. ADC trigger levels were set. Tapes were placed in all instrument recorders. After these bench checks were complete, the GITRs and Automatic Drop Counters were installed in the coracles. Following, the Water-Fraction and Gas-Fraction Samplers were installed. Prior to the installation of these samplers, each component was bench-checked for leakage.

Final selection of GITR locations aboard the Bausell were made. The shock mountings were then installed followed by the GITRs. (see Figure 2.6). On the USS Sioux, a sampling arrangement was installed for obtaining yield samples from the water patch. A hole was burned through the hull in the shaft alley 5 feet below the water line, and internal plastic piping was installed through which the patch sample could be drawn.

In order to refine the methods of laying the towed array, a rehearsal of this operation was conducted by the task force. A set of eight dummy coracles without instruments were used during this rehearsal. The tow was actually laid in three parts. These parts were: (1) tug to target ship, (2) target ship to zero raft, and (3) zero raft to end marker raft. The first part was laid from the tug, and the other two parts were laid from the LSD. The parts to be streamed from the LSD were pulled by M-boats. As the towline passed over the stern of the ship, stations 2 and 4 thru 8 were clipped in place in pre-positioned rings. Number 1, the station located in front of the target ship, was towed into place, because this portion of the tow was layed by the towing tug. Number 3 station which was located very close to one of the large rafts was towed into position also. This was done to prevent any possible collision between these two stations. During all operations, the tow was streamed in the fashion described.

The stations were recovered by small boats (LCMs) and towed to the LSD in all cases. Only the method of retrieving the towline was changed.

On the rehearsal, the towline was disconnected by hand at the target ship and the zero raft. These ends were then taken in tow by an LCM and returned to the LSD. During the actual shot, the towline was parted at the zero raft by the detonation of primacord just prior to burst time. This then made the downwind portion of the array free-floating. The radioactive water patch prevented the recovery boats from taking the zero raft end of the towline. Instead, they recovered the towline at the end-of-the-string marker raft and proceeded to pull it in a wide arc back to the LSD. After the line end had been passed to the LSD, which pulled it on board, LCMs removed the coracles from the towline and positioned them under the crane of the ship. The crane was outfitted with a hand-engaged grapnel which could be engaged quickly in the coracle tripod and held there until the crane could take a strain and pull the coracle out of the water.

After the sea trials, the project cleaned up all last-minute details, loaded all necessary equipment and personnel aboard the various ships, and the operation put to sea for the test site.

2.3.2 Sea Operations. Two days before the shot, the coracles were opened and arming began. Cables were connected, samplers were washed with distilled water, and the gas-fraction-sampler was charged with water. The instruments were run for a short time to check the recorders. The coracles were then closed to await final arming.

The final arming was started at H-8 hours. Coracles were reopened; the radiac trigger for the gas-fraction sampler was turned on and zeroed. The gas-fraction head and droplet counter head were installed, and the GITRs and ADCs started. The instruments in the well were checked with a stethoscope to insure that the motor in each of the recorders was running. At about H-6 hours, the coracles were closed, and the launching was started. Also at H-6 hours, the arming team was taken to the USS Bausell. The GITRs there were started, and the team left for the LSD with the last of the ship's company.

Difficulty aboard the weapon delivery ship and photography aircraft caused a 22-hour postponement of the shot, and all stations and towline were returned to the LSD. All GITRs and droplet counters required new recorder tapes and batteries. In some cases, the frangible valve in the gas-fraction sampler had detonated and had to be replaced. The pressure gages which provided the burst time fiducial were cut and lost on four stations. Replacement of damaged equipment and arming for the following day was started immediately. This was completed at H-13 hours the following day. The final arming was completed in the same manner as the day before.

After the coracles were launched and the Bausell GITRs armed, preparation for recovery was started. Personnel who were to enter contaminated areas, dressed out in protective clothing. Necessary equipment was assembled at the point of use. At H-3 hours, Project personnel were transferred to the USS Sioux to make final preparations for taking the contaminated water samples.

After the shot, personnel took their assigned stations and proceeded with the water sampling and the coracle recovery. The USS Sioux penetrated the edge of the radioactive water patch 18 minutes after burst time. The first water sample (5 gals) was taken at H + 20 minutes as the vessel pulled out of the area. Two more penetrations were made into the water patch at different locations, and water samples (5 gals) were taken each time. These were drawn at about H + 1 hour 53 minutes and H + 4 hours 10 minutes. A one-gallon portion of the second sample was allocated for air shipment to Los Alamos Scientific Laboratory (LASL). All of the water patch samples were transferred to the USS Yorktown and flown directly to NRDL and LASL for radiochemical yield determination.

The station recovery, which followed the same procedure as that rehearsed, proceeded through the day and into the early hours of the following morning. The far downwind end of the array was taken in tow by an LCM and pulled in a large semicircle upwind to the LSD. All stations survived the event, though station 5 had been capsized. The stations were all recovered by H + 15 hours. The following day the coracles were opened, and all taped data and samples were removed and packed for shipment to NRDL upon return to the staging area.

2.3.3 Data Reduction. The samples and data tapes were returned to NRDL for processing. All data reduction, sample decay counting,and chemistry had been started by D + 3. The data tapes were read out on the NRDL GITOUT (see Section 2.2.7). This data was then punched on to IBM cards and a computer used to reduce it to dose rate versus time. The total number of dose increments on the GITR tapes were counted and the total dose calculated. The ADC tapes were read out as pulses per unit time. Time was established on each using the known station start time and the shot time, or the pressure fiducial data.

Photographic data were analyzed from films made available by Project 1.2 of the NOL. The preshot and postshot positions of all stations with the exception of station 5 were ascertained. This station was never found in the postshot photos. Burst point was established and base surge sizes were determined where possible.

TABLE 2.1 SHOT DATA AND SURFACE WEATHER AT SHOT TIME

Yield, kt	
Burst depth	670 ± 20 feet
Water depth	17,140 feet
Burst time	2002:05.91Z, 11 May 1962
Zero Coordinates	124°13.3'W ± 0.3' 31°14.7'N ± 0.3'
Surface wind speed, knots	8 to 12 10.5 ± 0.5
Surface wind direction	From 293°T
Surface current speed, knots	0.5
Surface current direction	From 338°T
Waves	3 ft, crest to trough from 315°T
Swell	1 to 6 ft, crest to trough from 315°T
Firing Vessel Location	4348 yards from surface zero 298°T

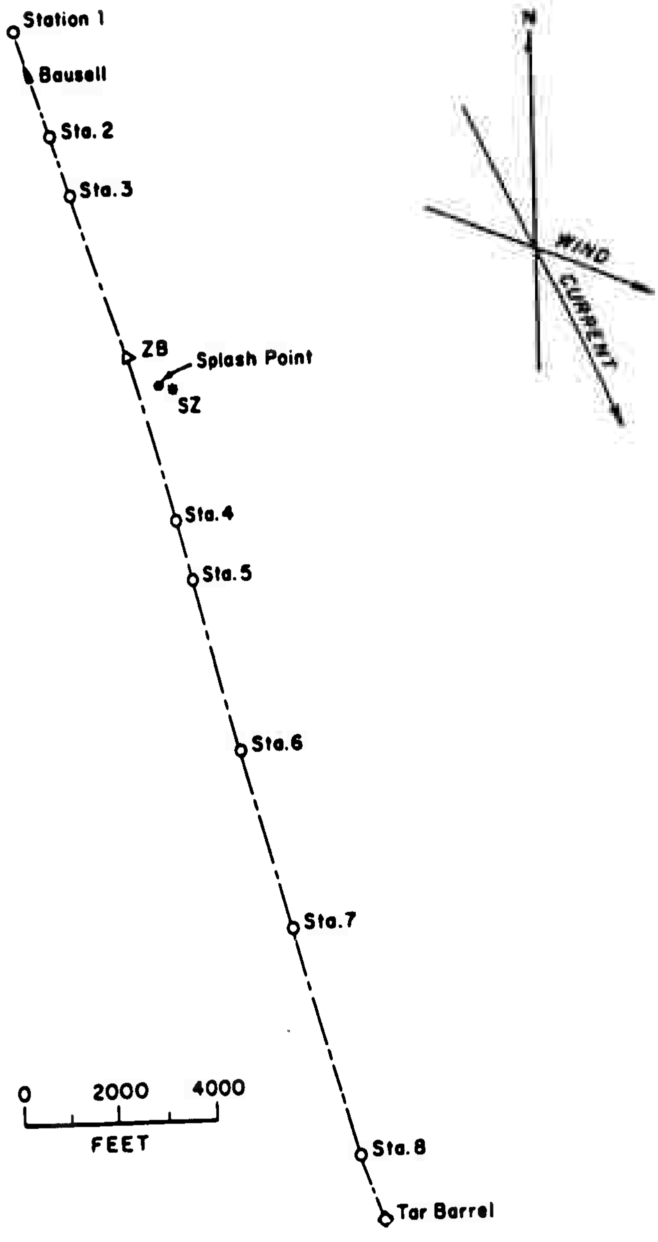

Figure 2.1 Preshot array.

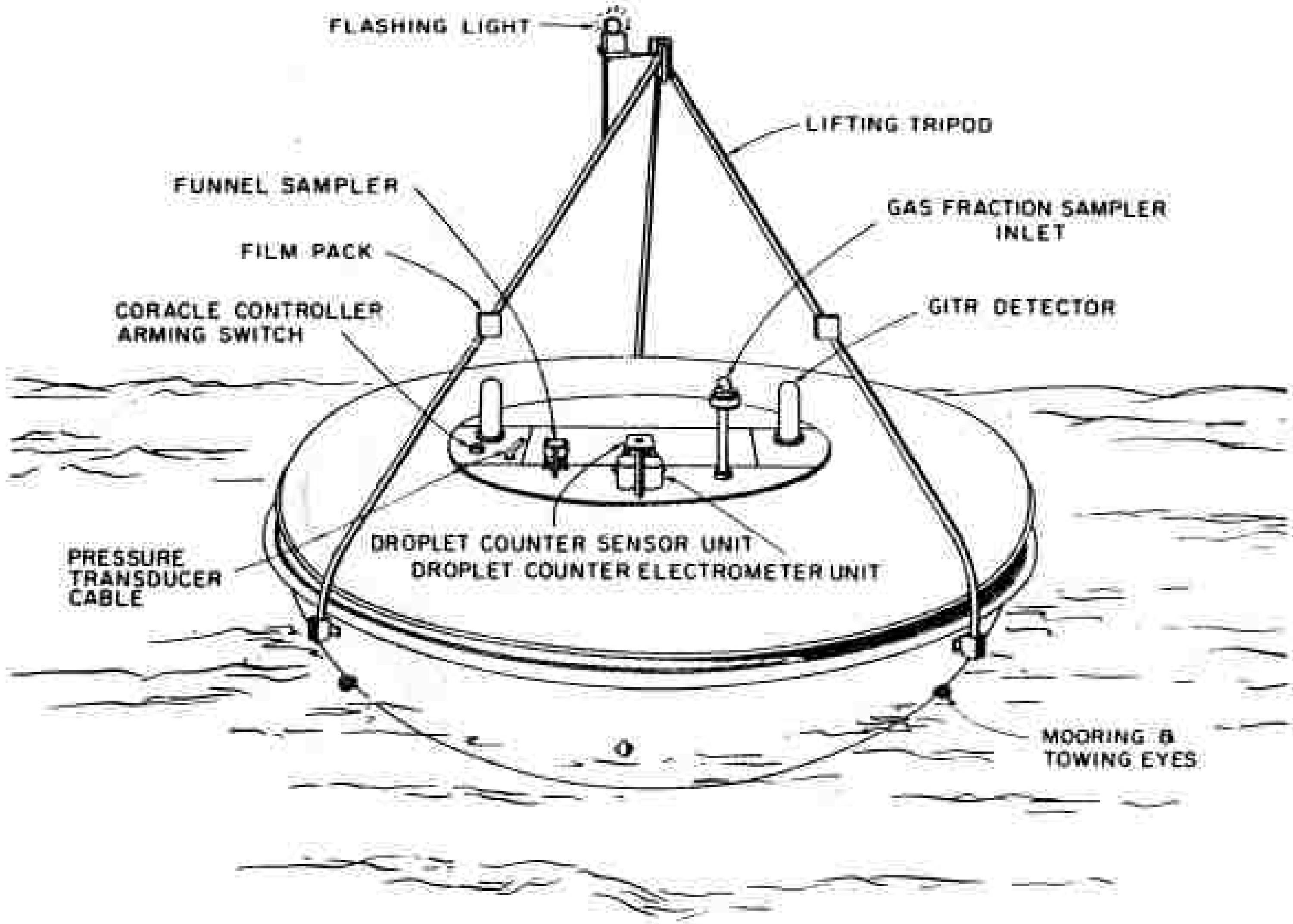

Figure 2.2 Coracle.

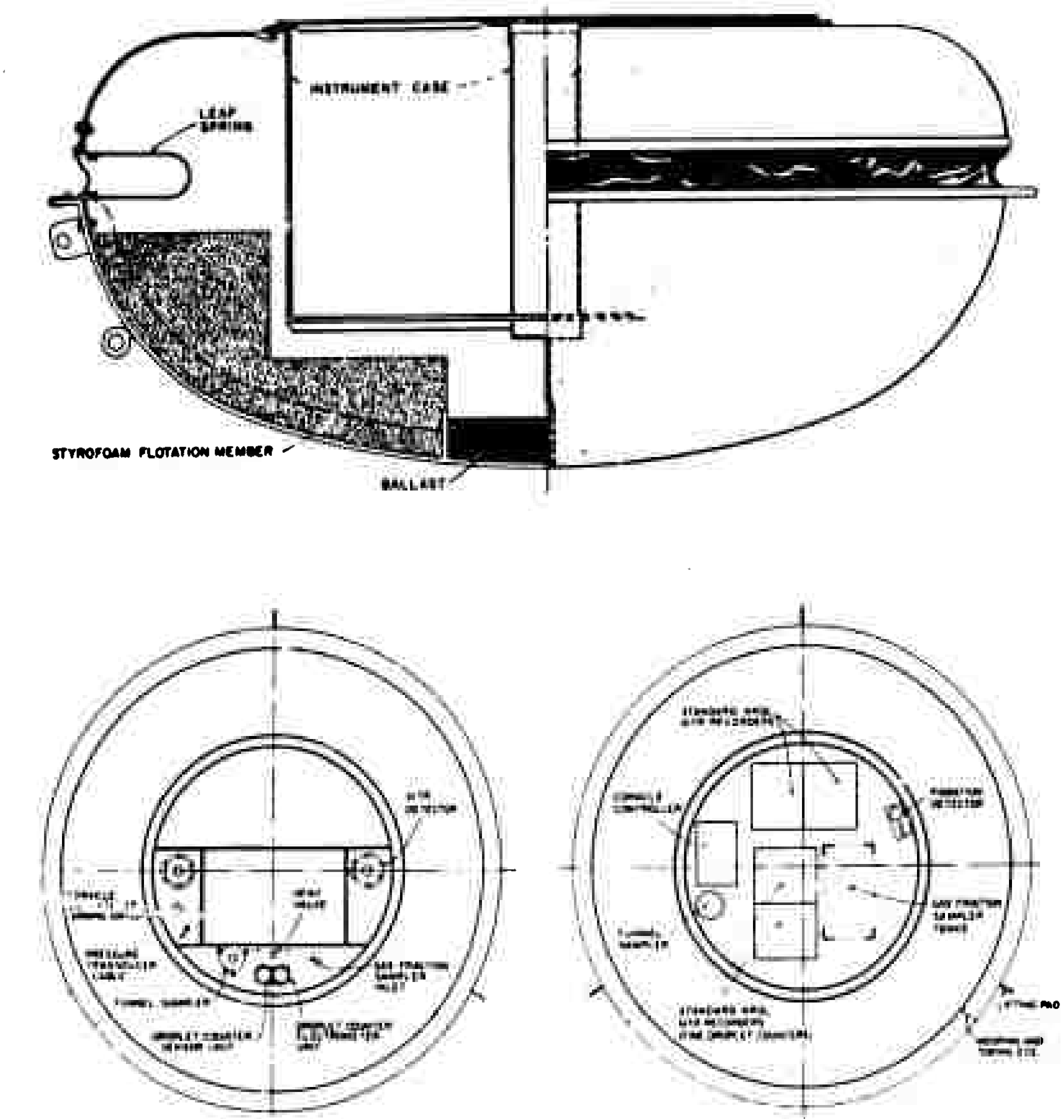

Figure 2.3 Coracle—simplified elevation, cross section, and plan view.

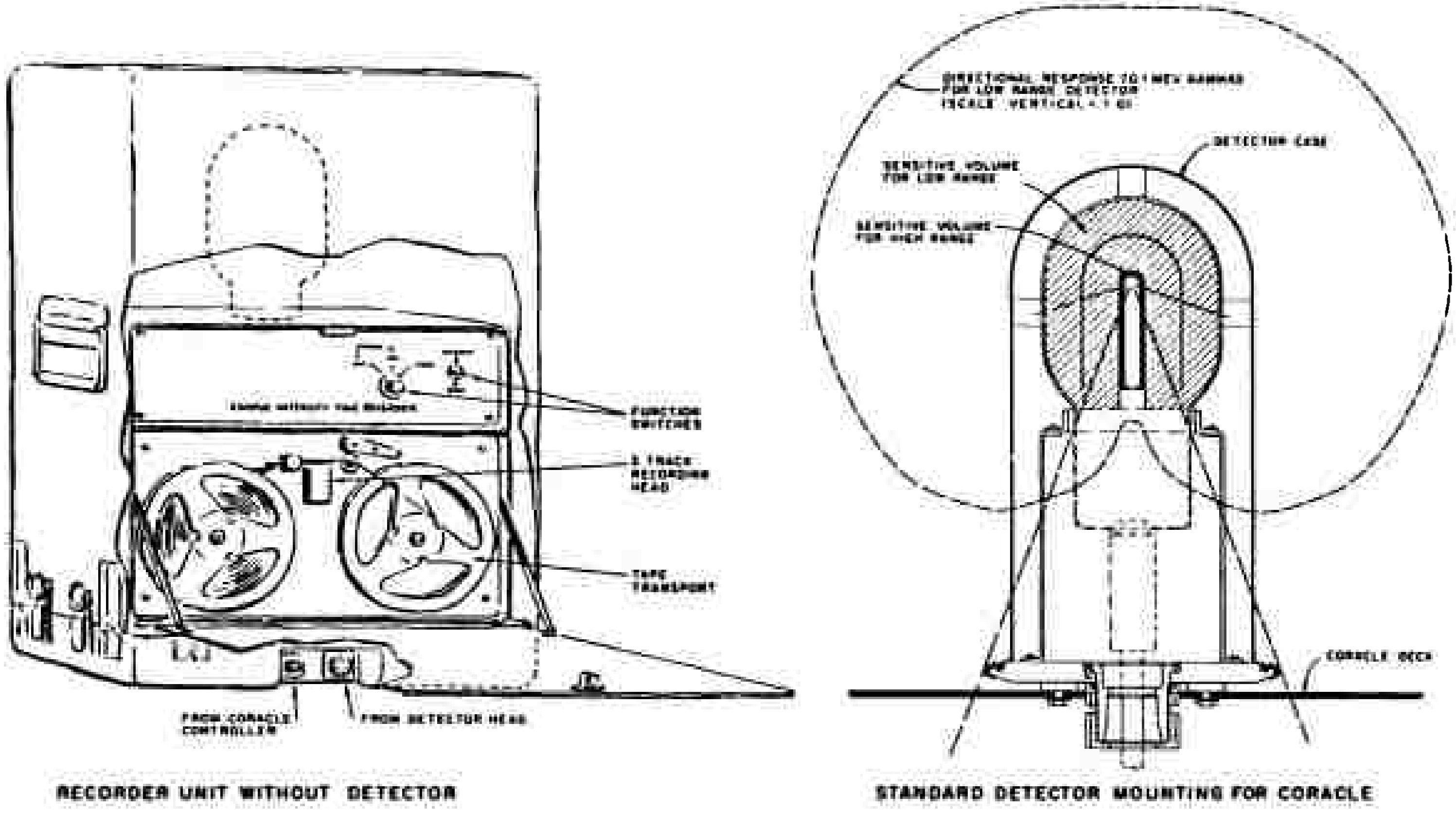

Figure 2.4 NRDL gamma-intensity-time-recorder.

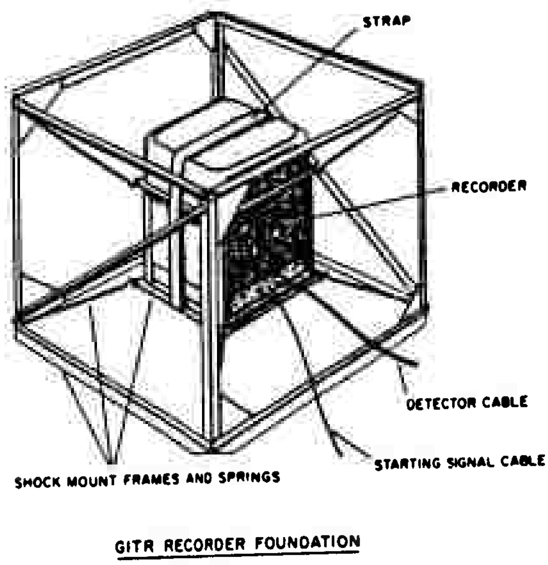

Figure 2.5 Shipboard GITR mounting.

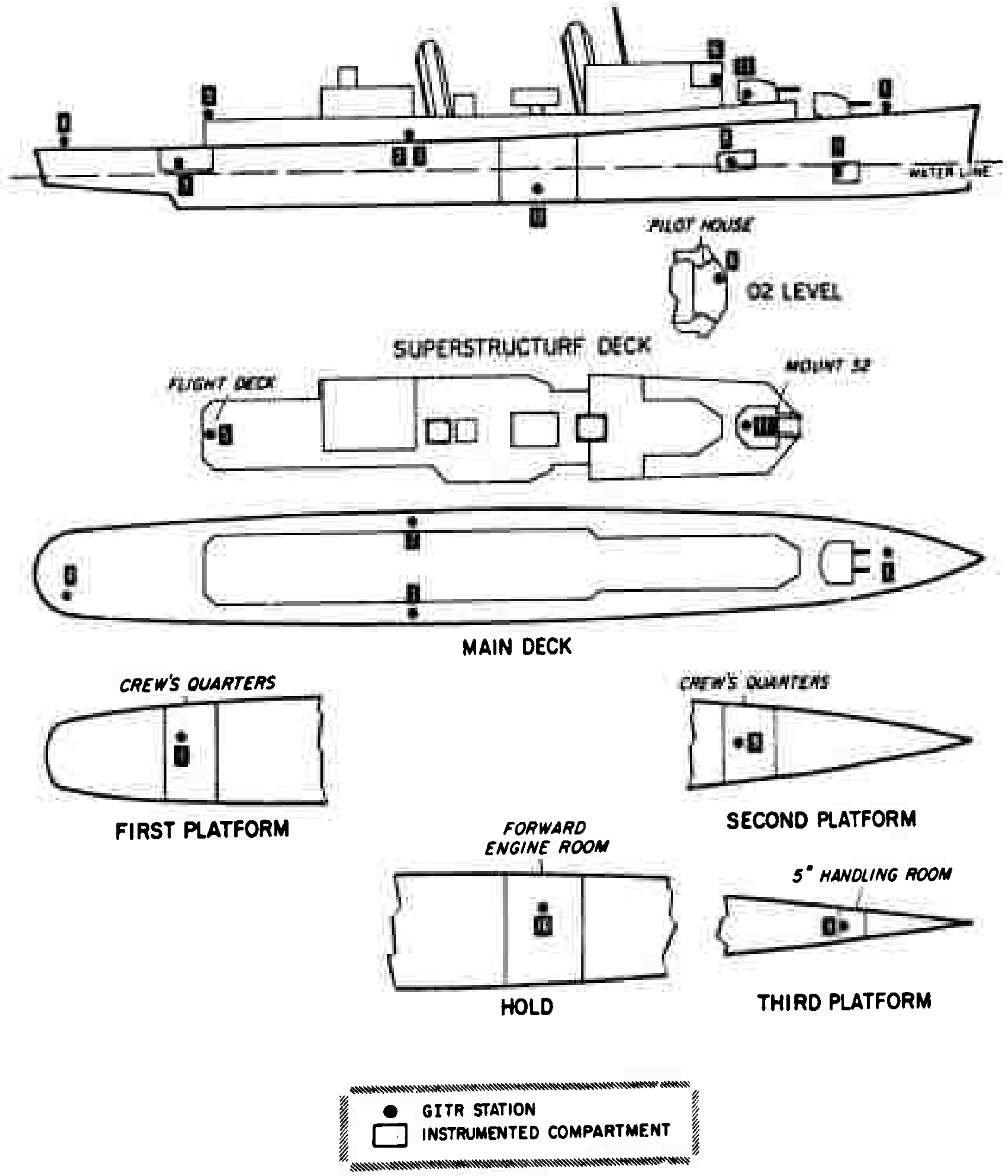

Figure 2.6 Shipboard GITR locations.

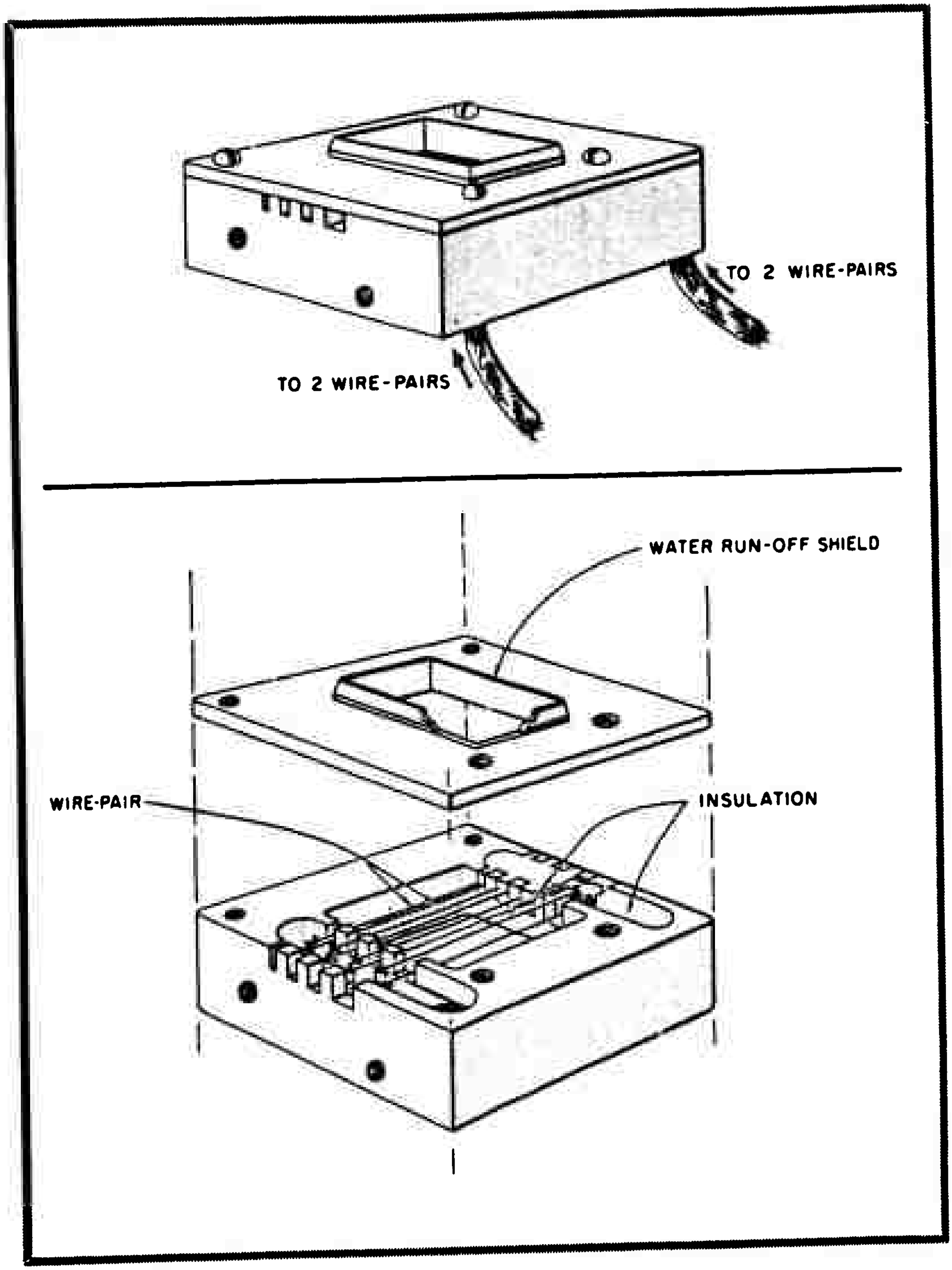

Figure 2.7 Droplet size counter head.

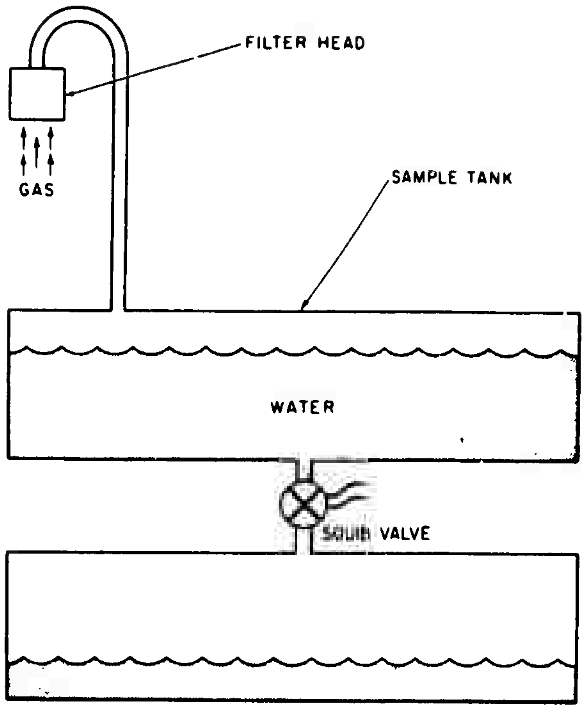

Figure 2.8 Gas fraction sampler.

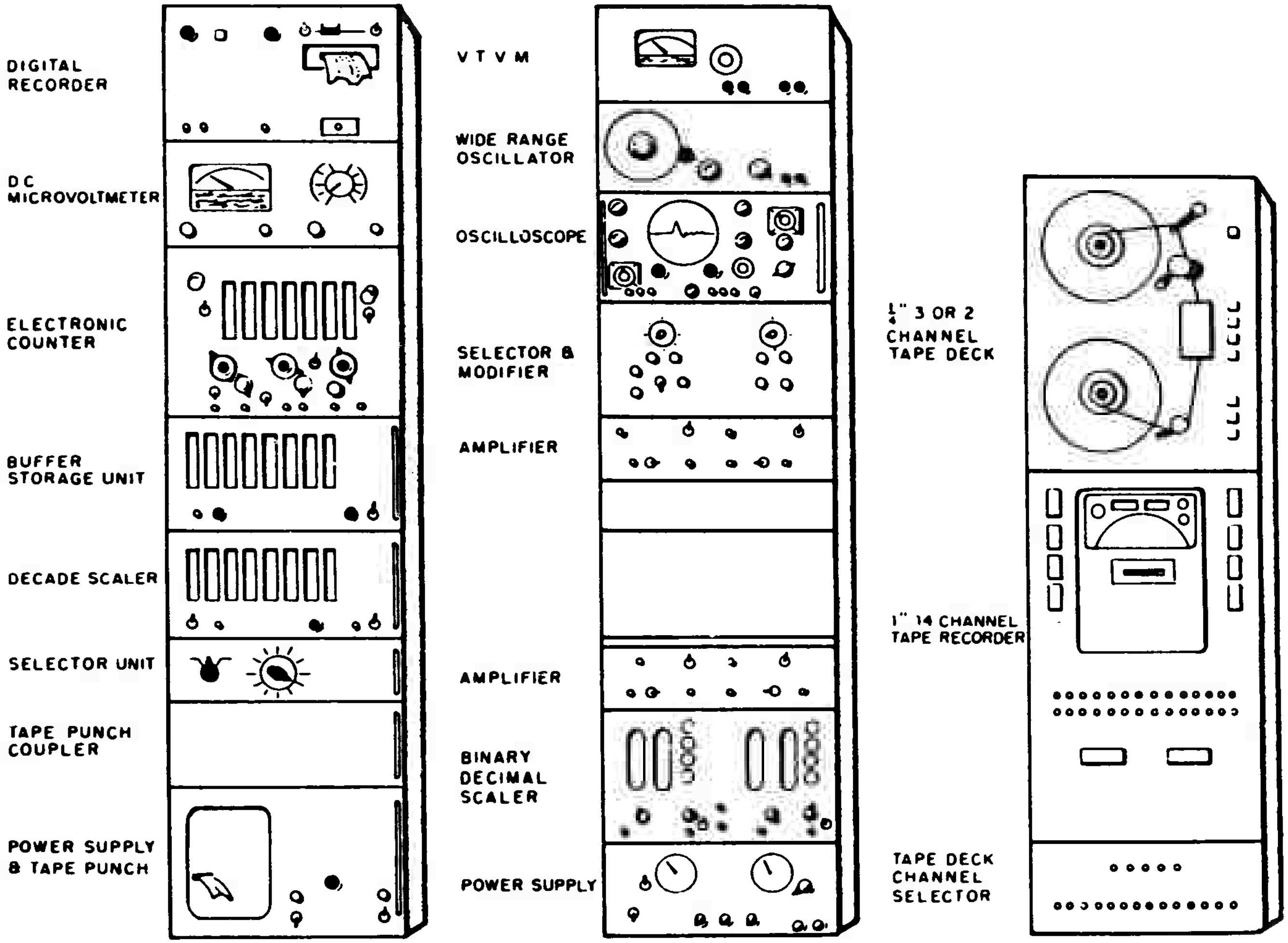

Figure 2.9 NRDL GITR readout (GITOUT).

Chapter 3

RESULTS AND DISCUSSION

3.1 GENERAL DESCRIPTION OF DATA

It was not the intent of the Project to perform a comprehensive investigation of the radiological aspects of the detonation of the ASROC weapon. The restriction of the station array to a single line of stations as given in Chapter 2 precluded a detailed documentation of the event. Strictly speaking, the data gathered at any station is applicable only to the location of that station. However, the data from the several stations could be extrapolated (since there was continuity) and the extrapolation used for the formation of a general picture of the event. The ultimate picture thus formed, however, is an implied one. This would be true to some extent in any case. In this instance, with the low station density and the skewed alignment of the array, the general picture is not as firm as it might otherwise have been. The gamma field histories of the stations, which, in part, formed the event picture, are shown in the Appendix.

3.2 EARLY TIME GAMMA FIELDS

The station GITR records showed a heterogeneous gamma dose rate history for all stations and the USS Bausell. There were, however, certain similarities between the GITR records. These similarities became quite clear when the records were compared with their location and the configuration of the surface effects as shown by the photographic data supplied by Project 1.2. Knowledge of the station preshot locations and the ambient meteorological and oceanographic conditions along with visual observation gave added meaning to the GITR records.

3.2.1 Gamma Fields, 0 to 5 Minutes. The first gamma field seen by the stations came from the plume as it erupted through the shock dome at H ≁ 7 seconds (see Figure 3.1). Before the plume had reached its maximum height, the gamma field created by it had reached out to 7,000 feet. Time of arrival of the first data at station 6 at 6,900 feet from surface zero was at H ≁ 13 seconds (see Figure 3.2). As the plume began to subside, the base surge appeared, and its growth is illustrated in Figures 3.3 through 3.8.

All stations upwind from surface zero that were not reached by the surge, i.e., Stations 1 and 2, had a single peak in their dose rate curve that occurred at about H + 1 minute (Figures A.1 and A.2). The peak arrived at a time when the plumes had completely subsided, and the surge appeared as a ring of water vapor, roughly circular in shape between 10,000 and 12,000 feet in diameter. The total dose at these stations was due to the shine from the surge and to a lesser extent the plume. By H + 3 minutes, the surge had reached its maximum extent upwind of about 6,500 feet. Its shape was quite irregular, and because of this, neither the Bausell nor Station 2 were in the surge even though they were within the maximum envelope of the surge (Figure 3.6).

Stations 4 and 5 were covered by the base surge at H + 24 and H + 34 seconds. During this time, it was expanding horizontally at the rate of about 100 ft/sec. The rate of growth was almost constant as indicated by measurements taken from the photographic data using Stations 4 and 5 as reference points. Since the surge was roughly circular at this early time, it was deduced from the symmetry of the event that Station 3 was covered by the surge at about H + 40 seconds. With this photographic evidence, it can be seen from Figures A.3 through A.5 that the first dose rate peak did not occur until after the stations had been covered by the surge. The dose rate experienced by these stations during the first minute and after they were covered by the surge may have come partially from the patch of contaminated water that was certainly in the process of formation. The separate contributions of the surge and the patch could not be determined from the data.

The early stages of the patch formation were completely obscured by the plumes and surge. The first view of the patch was not seen through the surge until H + 1½ minutes at which time the surge had grown to about 6,000 feet in radius. The water patch at this time was already 4,000 feet in radius and had reached Stations 3 and 5. Station 4 was probably in the patch almost from the start of its formation. As it expanded and reached Stations 3, 4, and 5, these stations were forced out of their original position in a radial direction from surface zero by the action of the water patch. At least the surface water of the patch appeared to be moving radially out from the center, carrying the stations with it. At some undetermined time during this period, Station 5 capsized. The cause of this is not known.

By H + 5 minutes, the base surge had reached its maximum upwind and crosswind dimensions. The upwind portion of the surge had already started to drift downwind, and the downwind extremities of the surge had reached out to a distance of 15,000 feet (see Figure 3.8). The gamma record of station 6 (see Figure A.6) for this entire period came only from the surge, since the water patch did not reach that station until much later. This gamma record, however, was not that of the direct downwind surge but more that of the west side of the surge as it passed over the station. This was due to the skewed location of the array axis with relation to the axis of the wind.

The gamma records of both stations 7 and 8 (see Figures A.7 and A.8) show this effect even more clearly. Time of arrival of the data at Station 7 was at H + 2 minutes, and the record was of much shorter duration than that of Station 6, indicating that the station was closer to the edge of the surge but still within it as it passed. The gamma field was also lower by a factor of two than that of Station 6. The first of the gamma field did not arrive at Station 8 until H + 7½ minutes. Again, this represented an edge transit of the surge over the station. The duration of the transit was about the same as for Station 7, but the gamma field was further reduced by at least a factor of two. This was to be expected in view of the comparatively later time at which the record was made.

Summarizing the gamma fields that existed during the first five minutes of the event, the initial field created by the plumes delivered high dose rates at the stations close to surface zero, but the field lasted for such a short time that the total dose accumulated from this source was not significant for vessels outside of the safe standoff distance based on shock considerations. At all locations outside of the base surge, upwind of the detonation point, the total gamma dose both from plume and surge was less than 25 r with peak dose rates not exceeding 500 r/hr. Within the surge as shown by Figure A.6, the dose rate ranged from 100 to about 4,000 r/hr from the surge only. Dose rates in the patch as shown by Figures A.3 and A.4 ranged from 1,000 to 30,000 r/hr from the surge and patch combined. Both the surge and the patch were visible to a surface vessel during the entire period.

3.2.2 Gamma Fields, 5 to 30 Minutes. At H + 5 minutes, the base surge was broken up into an elongated ring. The limits of this ring were not clearly visible due to its progressive evaporation. The entire mass of the surge was windborne. By H + 10 minutes it was practically invisible. Stations 1, 2, and the Bausell which were not reached by the surge had received over 90 percent of their total gamma dose. Station 2 had received 90 percent of its total dose by H + 13 minutes.

Stations 7 and 8 also received 90 percent of their total dose by H + 10 minutes. This undoubtedly was due to their location on the west edge of the surge. Had they been located directly downwind, their gamma record would have lasted until H + 30 minutes, and the dose rates and total dose would have been higher at least by a factor of 10, looking more like the first 20 minutes of the dose rate history of Station 6.

During the first 30 minutes, the water patch increased in size from 6,000 to 12,000 feet in diameter and was clearly visible from a surface vessel. Dose rates within the patch were recorded at levels ranging from 600 to 30,000 r/hr. Station 4, though it was moved radially outward, probably represents the gamma fields to be expected within the patch during this period. During the first 10 minutes, this record included the contribution of the base surge as it transited the station. Station 3 was also in the water patch during this time, though more toward the windward edge. Here also, the first five minutes of the gamma record included the gamma dose rate of the transiting base surge. The time period from H + 5 minutes to about H + 20 minutes represents the dose rate of the patch only. At that time, as shown by the rapid drop in dose rate, the station was towed clear of the water patch. The speed at which it was towed was about 1 knot or less. This fact in conjunction with the rapid decrease in the dose rate indicated a very steep gamma field gradient at the edge of the patch. The GITR record from the Sioux's first entry into the patch confirms this. The irregular nature of the dose rate record of this station also indicated that the gamma field at that station was far from uniform. One can only speculate as to the reason for this.

The motion of patch water seemed to be responsible for the manner in which the stations within the patch drifted radially outward from surface zero. If the patch water consisted of a layer of water spreading out over relatively clean ocean water, there would be a certain amount of mixing at the outer edges. This would give rise to an uneven distribution of the patch water at the edge of the patch and would tend to create a gamma field of which the record of Station 3 is representative. The presence of foam patches could have also contributed to this type of a record if the foam was more highly contaminated than the surrounding water.

Station 5 capsized at about H + 50 seconds. Whether the station was in the water patch at this time is not known. The record at this station for the period after capsizing was that of the gamma field that existed under about 2 feet of water. The passage of the base surge over this station was recorded through the bottom of the coracle but the record beyond H + 10 was that of the immediate subsurface of the water patch. The peak at H + 12 minutes could only have been due to the station converging with a patch of the water which had a higher specific activity than that of the surrounding water patch. This again indicated that the water patch was far from uniformily contaminated.

During this period, the base surge was carried downwind and became invisible due to the evaporation of its water phase. Its passage, however, was marked by the records of Stations 6, 7, and 8. The distinct dose rate peaks shown by Station 6 indicated that the surge was broken up into more or less discrete patches or clouds. This was the only clue to the difference in shape of the gamma records of Stations 7 and 8. There was no definite proof that Station 8 ever was in the surge. The gamma record of this station may well have been almost entirely from the shine of the surge as it was wind-driven past the station. When compared with the dose rate levels of Station 2, the higher levels experienced by Station 8 indicated that the station was at least at the edge of the surge. In any event, the location of Station 8 roughly marked the western edge of the surge as it drifted downwind.

The USS Sioux (ATF-75) made an entry into the water patch at H + 18 minutes to obtain the water samples for the radiochemical yield determination. The vessel approached the upwind edge of the patch at a speed of about 3 knots; the gamma field was found to rise very sharply (see Figure 3.9). The limit of the patch was sharply marked by white foam. Entry into the patch was limited to about 500 feet. Dose rates were approximately 1,000 r/hr, as shown by radiac meters and confirmed by the GITR detector 6 feet above the water and 6 feet from the side of the vessel. The vessel had hardly entered the patch when the dose rate forced her to leave. A 6-gallon water sample was nonetheless taken which contained 2.9×10^{12} fissions per liter. This was lower than had been expected at this early time. The two gamma dose rate peaks shown in Figure 3.9 have no apparent explanation. They may have been caused by the maneuvering of the vessel which could have brought less contaminated water to the surface near the detector. They may have been caused by the irregular contour of the edge of the patch through which the vessel passed.

Upon entering the patch at H ≠ 20 minutes, Project members noticed the presence of an invisible aerosol existing above the water patch to a height of at least 30 feet. The dampness of the aerosol could be felt on the skin. It was not part of the base surge but appeared to be generated by the water patch itself. Once free of the patch, the weather deck background varied from 10-20 mr/hr. Shoes and hands of exposed personnel read 400 and 100 mrad/hr, respectively. Fire hosing of the weather decks of the ship and showers for the personnel were effective decontamination.

The total gamma dose to the target vessel originated first from the shine from the plume and then from the shine from the base surge. The vessel was not at any time within the limits of the base surge, even though the maximum envelope of the upwind surge extended to the location occupied by the vessel. An indentation in the surge at that point kept the vessel from being covered by it (see Figure 3.6). Peak dose rates at the various shipboard stations all arrived at about H ≠ 1 minute, with 90 percent of the total dose arriving at from 3.8 minutes for location 8 to 10.5 minutes at location 4 (see Figure 2.6). The difference in the times was explained by the amount of natural shielding afforded the locations by the structure of the ship, the weakening of the gamma field around the ship with time, and the cutoff sensitivity of the GITR. Dose with respect to time and total dose for all of the shipboard locations is given in Table 3.1.

The dose rate histories are given in Figures A.9 through A.16.

The dose rate and total dose for all of the weather deck stations was comparable with coracle Stations 1 and 2, taking their distances from surface zero into consideration. There was practically no shielding effect from the ship's structure at these locations. At locations below deck, the shielding afforded by the structure was evident in the reductions in dose rate and total dose by a factor of from 10 to 100.

It must be emphasized that, though the maximum total dose aboard the vessel was low, the location was within the envelope of the upwind surge. Had the array been oriented as little as 15 degrees to either side of its location, the surge might well have reached that location with dose rates increased by a factor of 100.

<u>3.2.3 Gamma Fields, 30 Minutes to $2\frac{1}{2}$ Hours</u>. By H ≠ 30 minutes, the base surge had been completely swept from the area of the station array by the prevailing 10-knot wind. The contaminated water patch was still visible from the air and surface ships and was the only remaining source of radiation. Both Stations 5 and 4 were in the water patch (see Figures A.17 and A.18) probably near the southern edge. Station 6 was still clear of the patch and relatively close to its preshot location. The record of this station (see Figure A.19) shows the approach of the patch, by a distinct and continuing rise in the dose rate at that location. Overhead photography shows Stations 4 and 6 within 1,000 feet of each other at the south edge of the patch at H ≠ 56 minutes (see Figure 3.10). At this time, the limits of the patch were marked by a disconnected ring of foam streaks that was barely visible in the photography. The size and shape of the patch would have been difficult to judge from the deck of a surface vessel. Station 5 could not be located, and the failure to do so was probably due to the station's being capsized. With the orange-colored bottom rather than the white top showing, photographic location of the station was impossible. But it was still attached to Station 4 by the towline, and had to be within 1,000 feet of that station. The lack of any gross discontinuities in its gamma record showed that it was probably still in the patch.

The sharp reduction in the dose rate of all three stations at about H + 1 hour indicates that they became separated from the water patch at that time. The towline of Station 4 chafed apart, and the station started to drift independently, with the wind, from the other stations. The other stations also drifted free of the patch, due to the action of the wind, though their drift rate was much slower due to the drogue action of the towline which still connected Stations 5 through 8. Even at this relatively late time, the dose rate level existing at least in portions of the patch as indicated by the gamma records of these stations was high enough to be of tactical significance. In particular, the record of Station 4 indicated that the water patch, at least for the first hour after the detonation, was tactically dangerous for surface vessel entry. The record of that station showed a total dose of 4,000 r for the first 50 minutes.

At about H + 3 hours, the Sioux made its second entry into the patch, this time in the southern quadrant. Though not as steep as in the case of the H + 20 minute entry, the gradient of the gamma field was still quite steep as shown in Figure 3.11. The vessel's speed, as in the case of the first entry, was about 3 knots. Even at this time, the gamma dose rate was high though down by a factor of 10. The 5-gallon water sample taken contained approximately 10^{13} fissions/liter. By H + 4½ hours, as shown by the gamma record of the third Sioux entry into the patch, this time in the northwest quadrant, the gamma field was reduced by another factor of 10 as shown in Figure 3.12. The patch was not visible from the deck of the Sioux during either of the last two entries. There were no traces of foam. Radiac instruments were the only guide for conning the vessel into the patch, along with an uncertain dead-reckoning track kept by the vessel and shown in Figure 3.13. The third entry of the Sioux into the water patch for the purpose of obtaining water samples was the last contact that the Project had with the patch. The sample taken contained 2.5×10^{12} fissions/liter. Further transits of the patch were made by the Sioux for the NRDL/AEC Project. The results of this Project are reported in Reference 8.

3.3 RESIDUAL CONTAMINATION

In most cases, the GITR tapes had run out before recovery of the stations could be made. Upon recovery, each station was monitored with hand radiac instruments prior to any decontamination. Only those stations that had been in the contaminated water patch showed any appreciable contamination above background, which by recovery time was 10 to 15 mr/hr on the flight deck of the Monticello. The high background was caused by the recovery of contaminated towline. Those stations that had been in the water patch showed levels ranging from 100 to 250 mr/hr, 3 feet above the coracle deck. Station 5 had the highest level of contamination due to the hangup of contaminated water resulting from its overturn. Back decaying of these readings, using a normal fission product decay curve, indicated that the contribution of the deposit dose left on the station was not significant when compared to the total dose experienced by the station. This condition was not too conclusive as data, since surface wave action may have partially decontaminated the station during the time it was being towed back to the Monticello. On the other hand, some of the stations, particularly Stations 5 through 8 were inadvertently towed through the west edge of the water patch during recovery. This may have served to increase rather than decrease the amount of contamination found on these stations at recovery time.

Subsequent to the three entries of the Sioux into the contaminated water patch to obtain water samples, she returned to the patch to carry out the remainder of a 24-hour survey of the patch for the NRDL/AEC Project. Upon her return to port on H ≠ 3 days, monitoring of the vessel showed no significant contamination on either the ship's hull or in the salt water systems of the machinery which had to remain open during transits of the patch. No decontamination of the weather decks was necessary. The only precautions taken during the operation were the securing of all but the essential salt water system and the firehosing of the aft deck after the first entry into the patch. This indicated that deck contamination by the water patch was negligible and that normal steaming in clear water was effective as a decontamination measure for those salt water systems necessary to the operation of the vessel.

Upon return to port, the coracles were again monitored and found to be contaminated with an alpha emitter, identified later as (Pu^{239}). Only those coracles that had been in the water patch were thus contaminated and then only on a strip 8 to 12 inches wide at the waterline. Maximum readings on the most highly contaminated coracle was 2.6×10^5 dis/min/ $60 cm^2$, with the average being from 3 to 5×10^4 dis/min/$60cm^2$. The three remaining coracles were similarly contaminated but with maximum readings of from 1.2 to 4×10^4 dis/min/$60\ cm^2$ and average readings of from 4 to 10×10^3 dis/min/$60cm^2$. The fact that the contamination was restricted primarily to the waterline indicated that the contamination was deposited from the surface of the water, perhaps from the surface foam that so clearly marked the patch limits at early times. This does not preclude the likelihood that this alpha-emitting material was distributed in depth in the patch.

3.4 YIELD DETERMINATION

Determination of the yield of a nuclear weapon by radiochemical means involves determination of the number of fission events represented by the fission products in a given sample and of the fraction of the original fissionable material contained in the sample. Determination of the number of fission events producing the fission products is done by measuring one or more fission products whose fission yield is well established. The nuclides used here are Mo^{99} and Nd^{147}. Determination of the original fissionable material fraction is done by measuring one or more elements which were originally present in the weapon in a known amount. Elements such as uranium and plutonium are commonly used. Because the concentration of naturally occurring uranium in sea water is comparable to the concentration of uranium from the bomb debris resulting from this detonation, uranium could not be used satisfactorily for measurement of the bomb fraction. Plutonium was thus employed for this purpose. Numerous other radiochemical determinations were required to correct for other nuclear reactions occurring in the detonation, for fractionation which was extensive in one of the three samples, for fission in more than one fissionable nuclide, and for fission with high-energy (14 Mev) neutrons.

All radiochemical determinations were completed. Using these results, the yield of the weapon was calculated as being

This figure supersedes the value

of percent previously reported in Reference 9.

3.5 ADDITIONAL MEASUREMENTS

As given in section 1.1.4, physical measurement and sampling of the base surge was attempted. Because of the failure of the triggering control for the gas-fraction sampler, no samples of the base surge gas fraction were obtained. Though the droplet counter operated properly, difficulties arose in the calibration of the droplet counter detector head. Interpretation of the droplet counter data cannot be done until the calibration difficulties are resolved.

Suitable samples of the base surge rainout and of the contaminated water patch were obtained. The rainout samples were collected by the bottle-funnel collectors at each station. The water patch samples were obtained as related in Sections 3.2.2 and 3.2.3.

All stations collected measurable amounts of liquid in the funnel-bottle collectors. However, collections at the two far downwind stations were not active enough to warrant radiochemistry. The weak specific radioactivity of these samples strongly suggested that they were considerably diluted by ocean water splash. The radioactive decay of the samples from the far upwind stations which were known to have escaped engulfment by the surge tended to match the decay of the radioactive patch water with which they inadvertently came in contact during recovery of the stations. This suggested that some contamination of the other samples may have occurred from sea splash. One of the three water samples taken for the determination of the radiochemical yield of the weapon was decay counted for comparison with rainout decay curves.

Table 3.2 presents the principle results of the physical and radiochemical analysis of the funnel-bottle rainout samples together with similar data recorded for the three yield-determination samples. The notable feature of these data is the trend toward increasing R-values, or enrichment of those daughter nuclides having moderate half-life rare gas precursors, as a function of the time of arrival of the rainout. This result is in qualitative agreement with the fractionation hypothesis (Reference 5) and confirms similar results recorded in Operation Hardtack. The slight depletion of these daughters found in the water patch samples is also an expected consequence of this hypothesis.

Two sets of radioactive decay analyses were accomplished. One set involved the use of a NaI(Tl) crystal well counter, the other a 4π ion chamber. Figure 3.14 represents the well counter decay curves plotted with an arbitrary radioactivity scale. The curves were purposely oriented in the fashion shown to emphasize the changing shape characteristic as a function of the time of arrival of the rainout liquid. This shape change is quite regular for the upper four curves and is attributed to the increased quantity of Ba^{140} and La^{140} in the successive samples. The lower two curves (Station 7 and 8) should have followed the trend of the upper ones, since rainout arrival at the stations was later. Instead, their shape places them somewhere between that of the radioactive patch water sample and the radionuclide enriched rainout samples. This reversal of shape trend was probably due to a small collection of rainout being contaminated by a larger quantity of sea-splashed patch water.

Figure 3.15 represents three 4π ion chamber decay curves developed by the method of C.F. Miller (Reference 10). Superimposed on two of these are the data points of decay curves produced by rainout samples. The radioactivity scale is arbitrary, and the curves are purposely oriented in the fashion shown. This emphasizes the shape similarity between calculated decay curves and the actual ones when the theoretical curves have been altered by inclusion of the same excess quantity of Ba^{140} and La^{140} contained in the real samples.

These two sets of decay curves generally support the findings shown by the radiochemical analyses. They are in accord with the fractionation hypothesis and confirm similar results found in Operation Hardtack.

Within the limits of the Project's participation, the effectiveness of the Project was measured by the accumulation of data from all instruments and the reliability of that data. This was modified by weighting the various instruments and their data in accordance with the importance to the Project of the objectives which they served. The overall effectiveness of the Project was about 80 percent in achieving its original objectives.

TABLE 3.1 TOTAL GAMMA DOSE AT ALL GITR STATIONS

Station No.	Distance from SZ (ft)	Total Gamma Dose (r)	Time to 90% Total Gamma Dose (min)
1 - Upwind[a]	7,250	.375	7
2 - Upwind[a]	5,170	22	12.5
3 - Upwind[b]	3,980	923	19
4 - Downwind[b]	2,430	4,250	46
5 - Downwind[b]	3,590	207.5	16*
6 - Downwind[b]	6,890	344	60
7 - Downwind[c]	10,340	38.5	10
8 - Downwind[c]	14,790	20	17.5
DD-845 Shipboard	6,400		
1 - Forecastle[a]		0.69	9.9
4 - Fantail[a]		2.1	10.5
5 - Flight deck[a]		1.9	10.4
7 - Aft crew's quarters[a]		0.31	7.6
8 - Forward crew's quarters[a]		0.062	3.8
9 - 5" Ammo handling room[a]		.008	4.6
10 - Fwd Engine room[a]		.008	8.1
11 - 5" Gun turret, Mt. 52[a]		2.8	7.4

(a) Shine from plume and surge only.
(b) Surge and water patch.
(c) Surge only.
* Station capsized.

Page 53 Deleted.

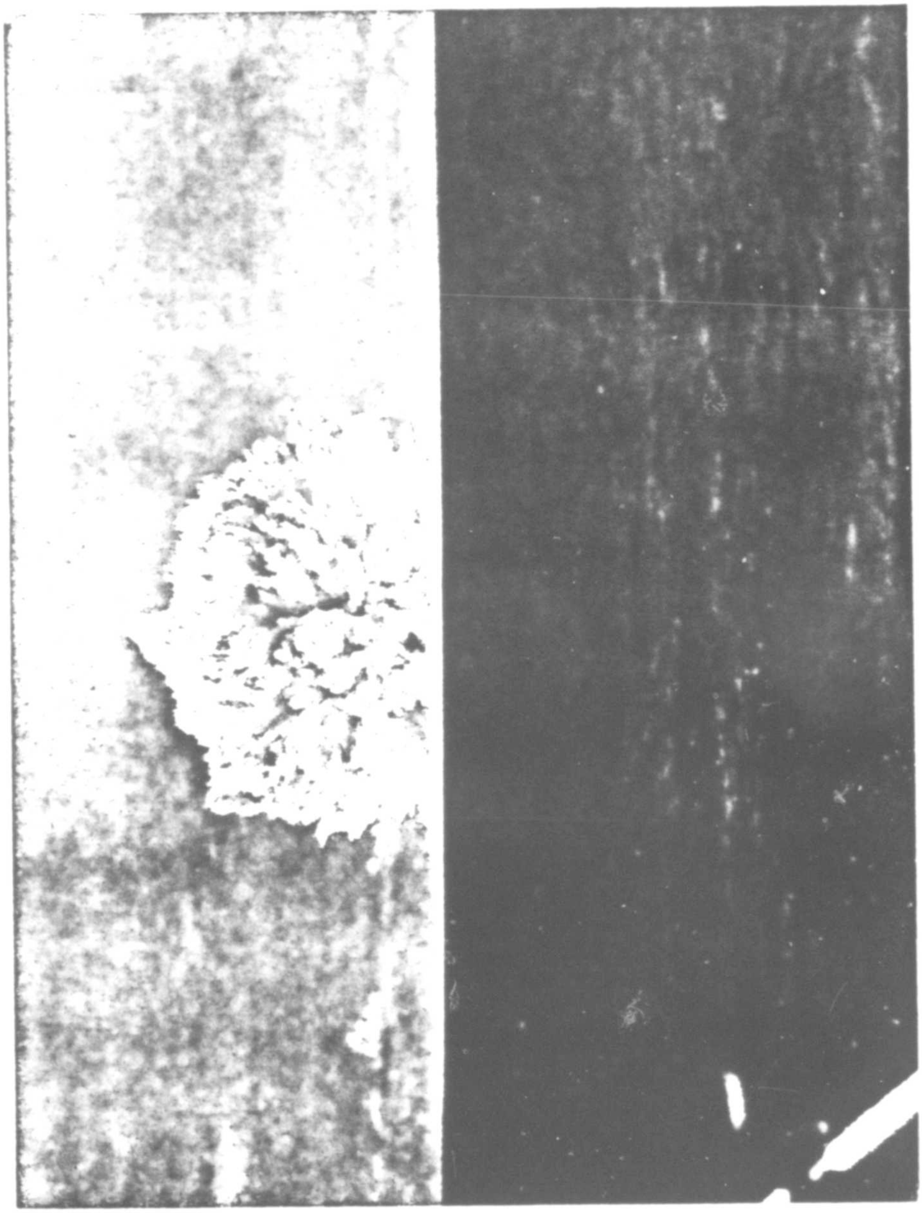

Figure 3.1 Plume at H + 10 seconds. (NRDL photo)

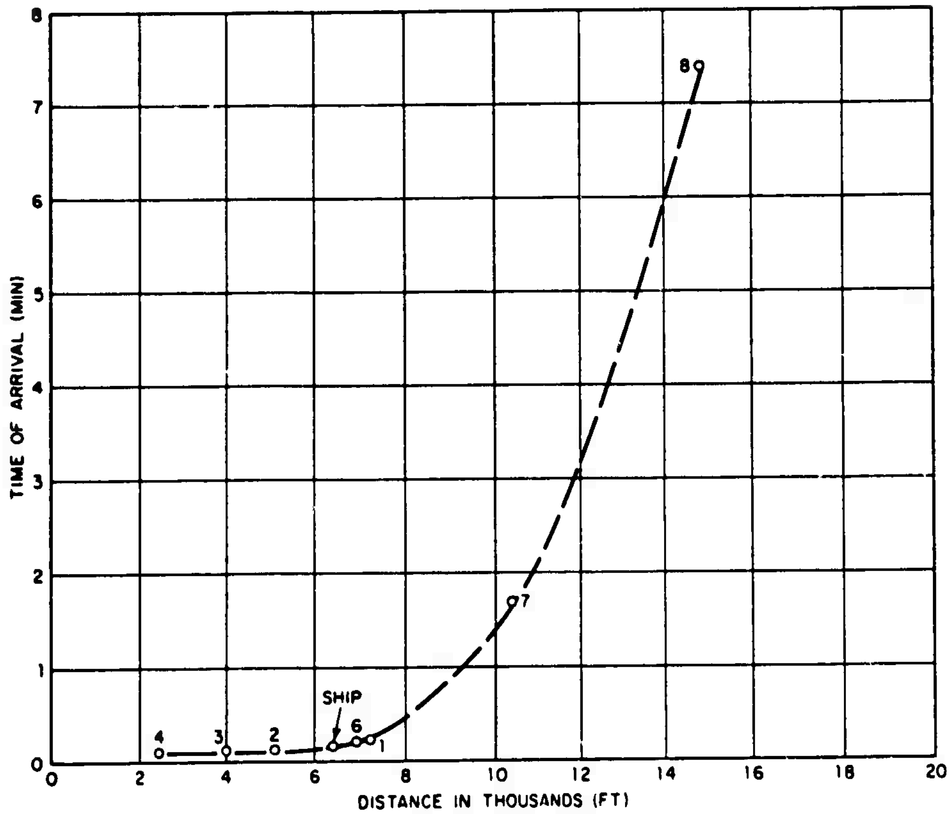

Figure 3.2 Data arrival time at station locations.

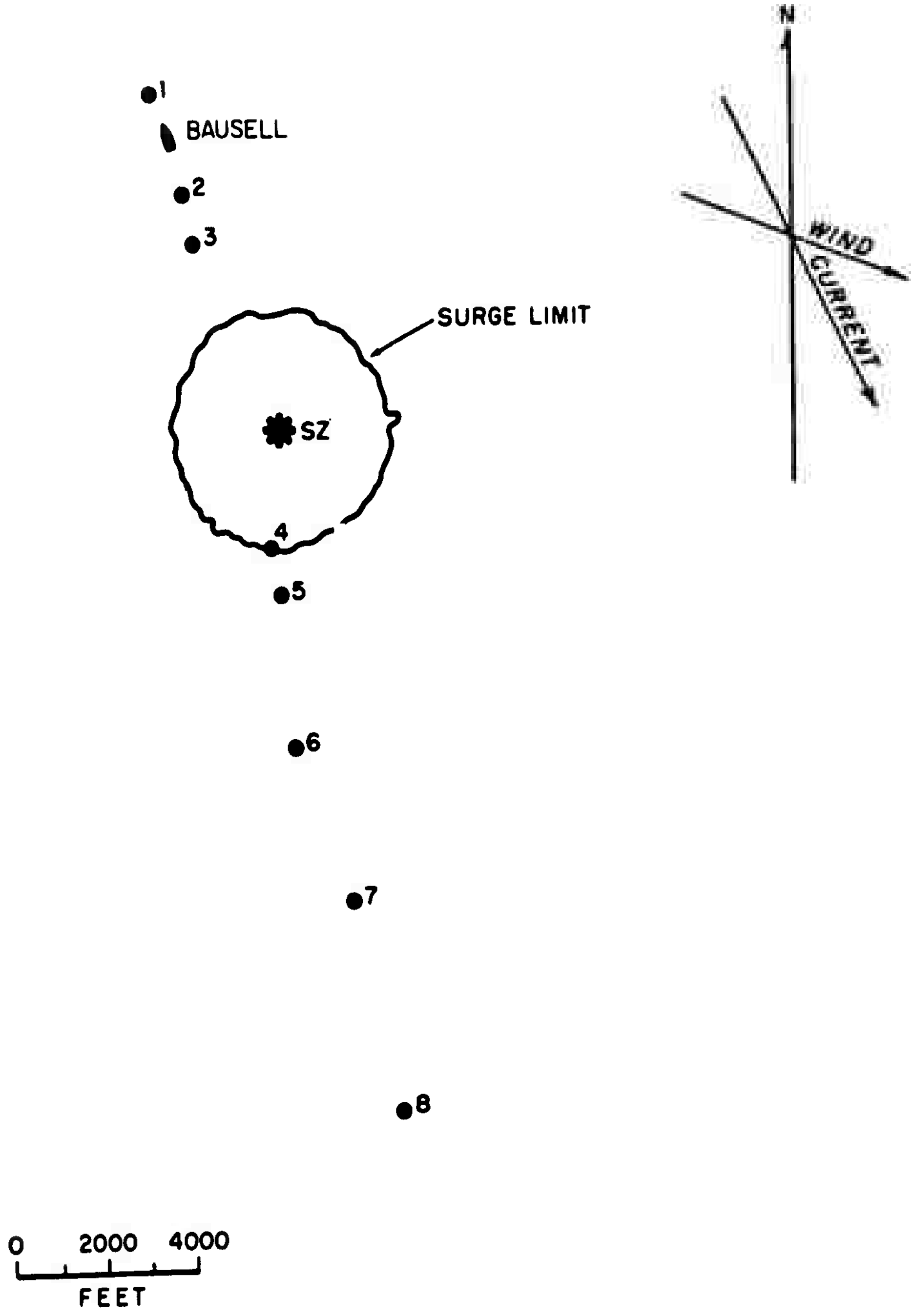

Figure 3.3 Visual base surge contour at H + 24 seconds.

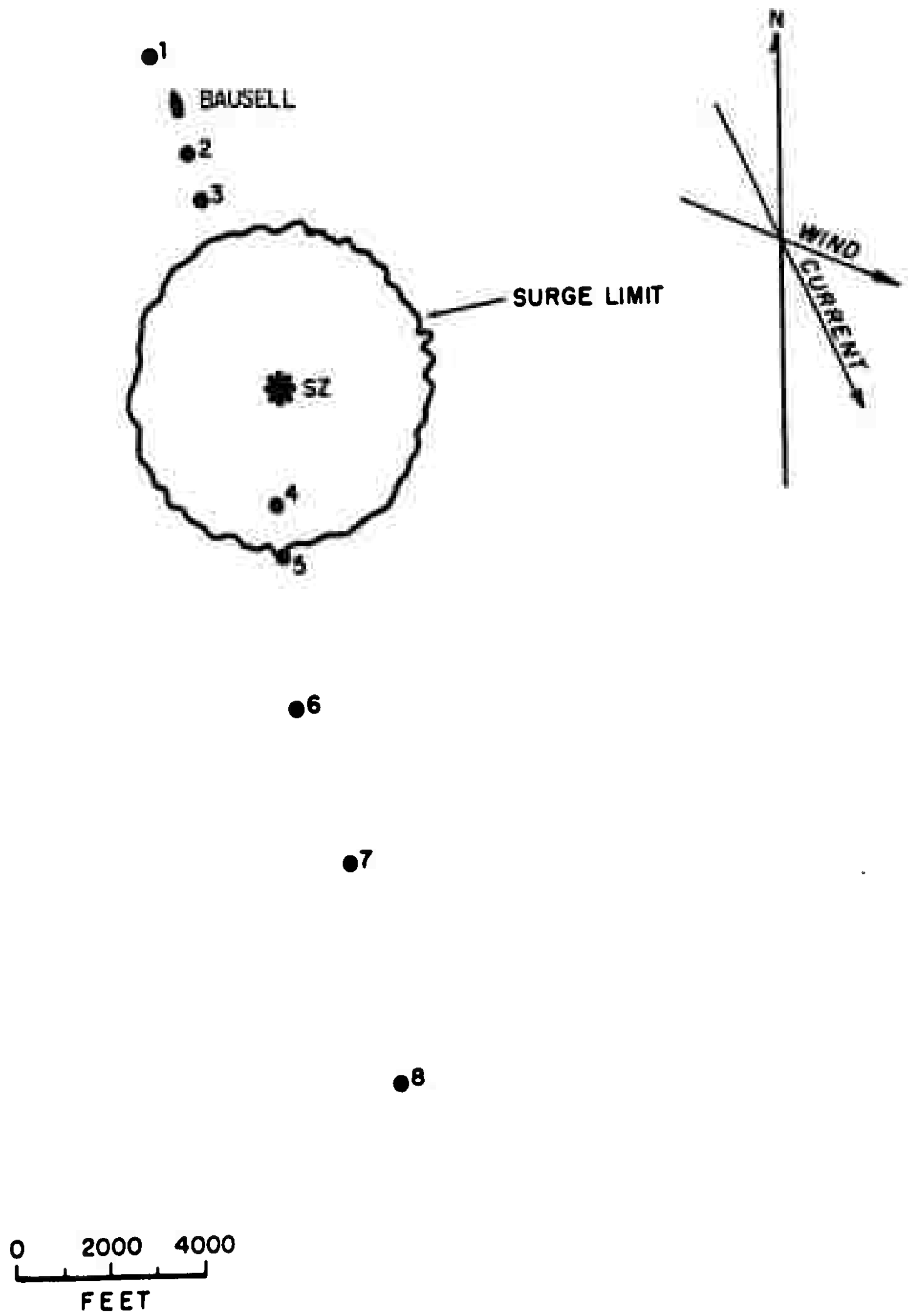

Figure 3.4 Visual base surge contour at H + 34 seconds.

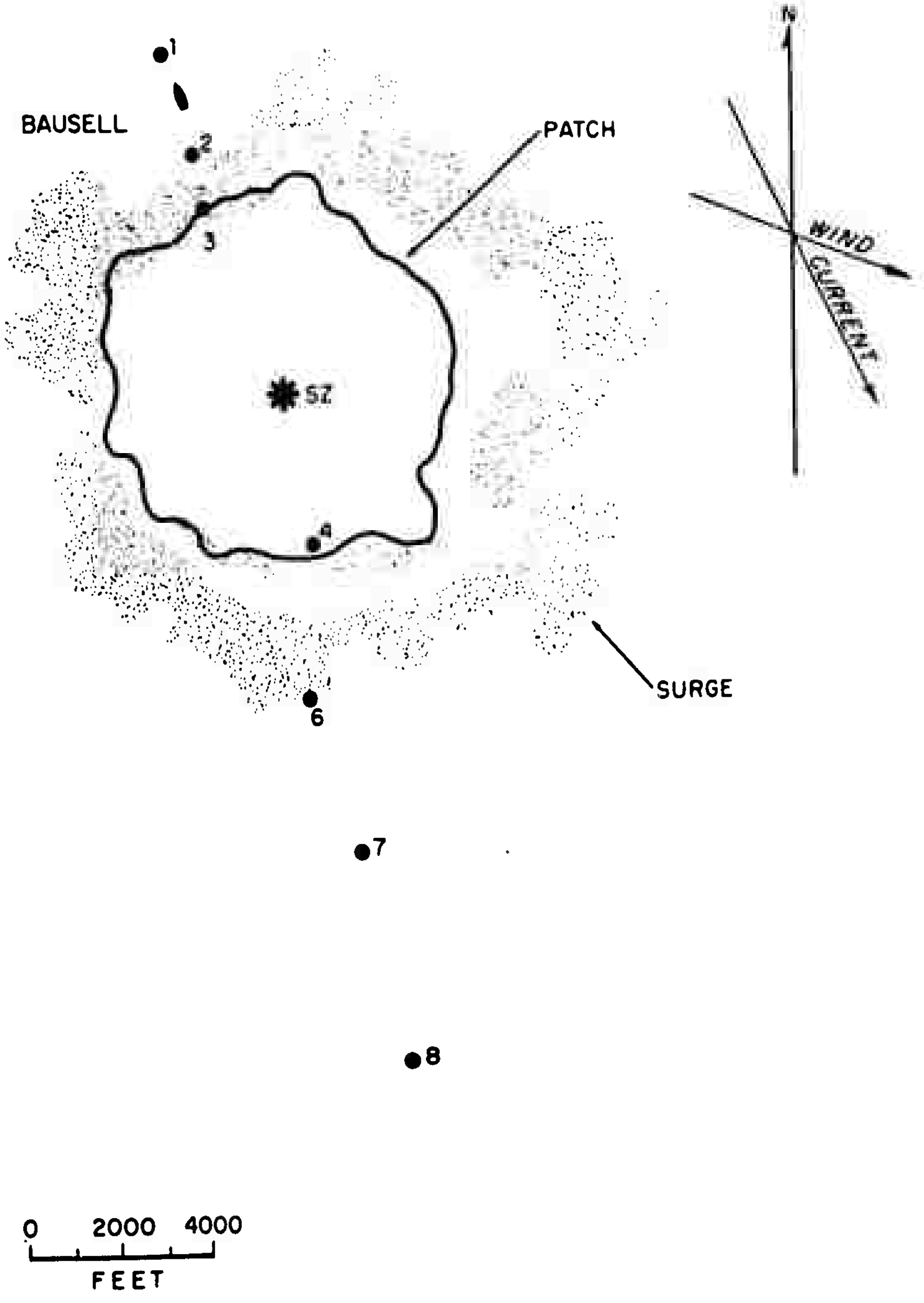

Figure 3.5 Approximate base surge and water patch configuration at H ≁ 2 minutes.

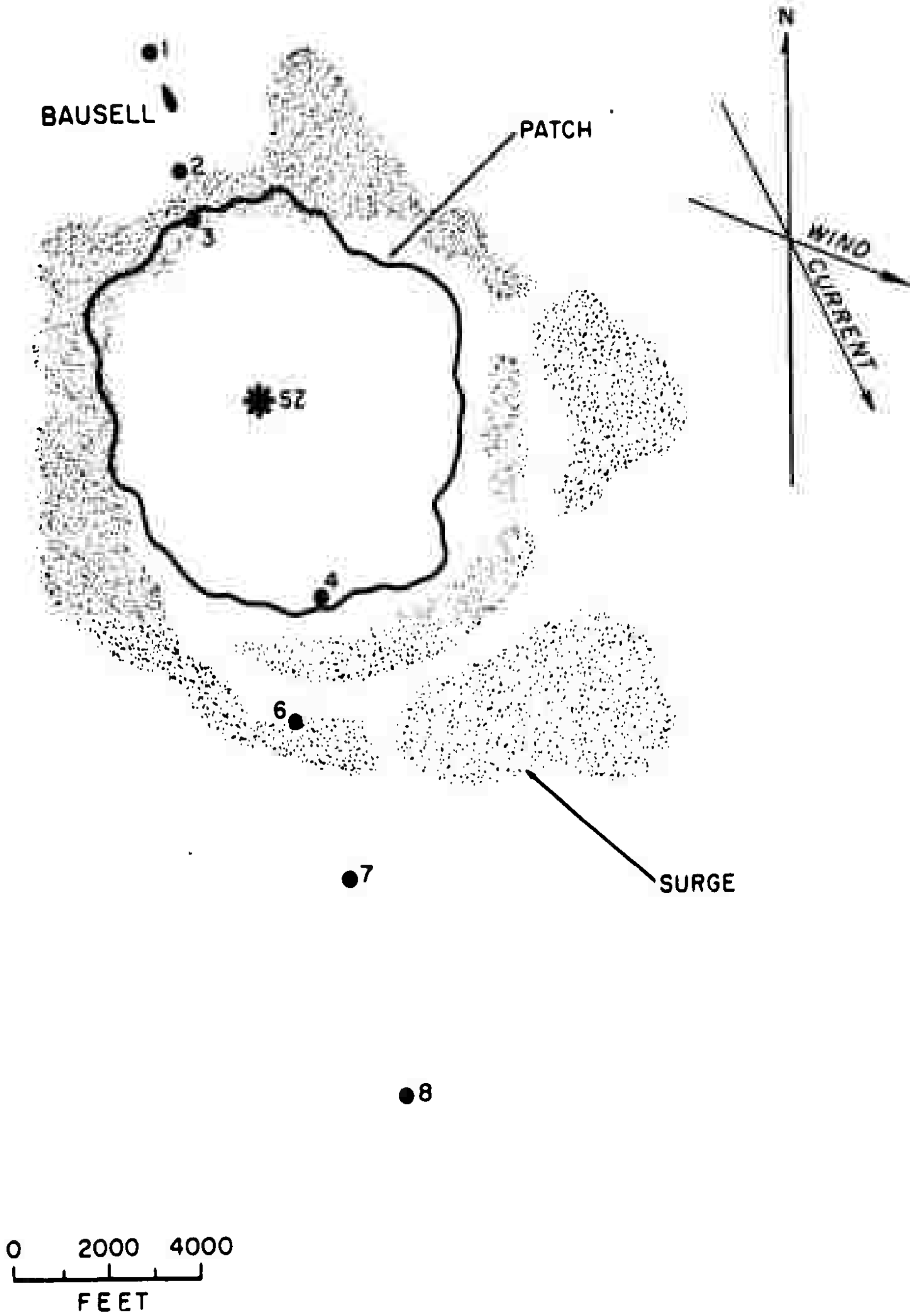

Figure 3.6 Approximate base surge and water patch configuration at H ≁ 3 minutes.

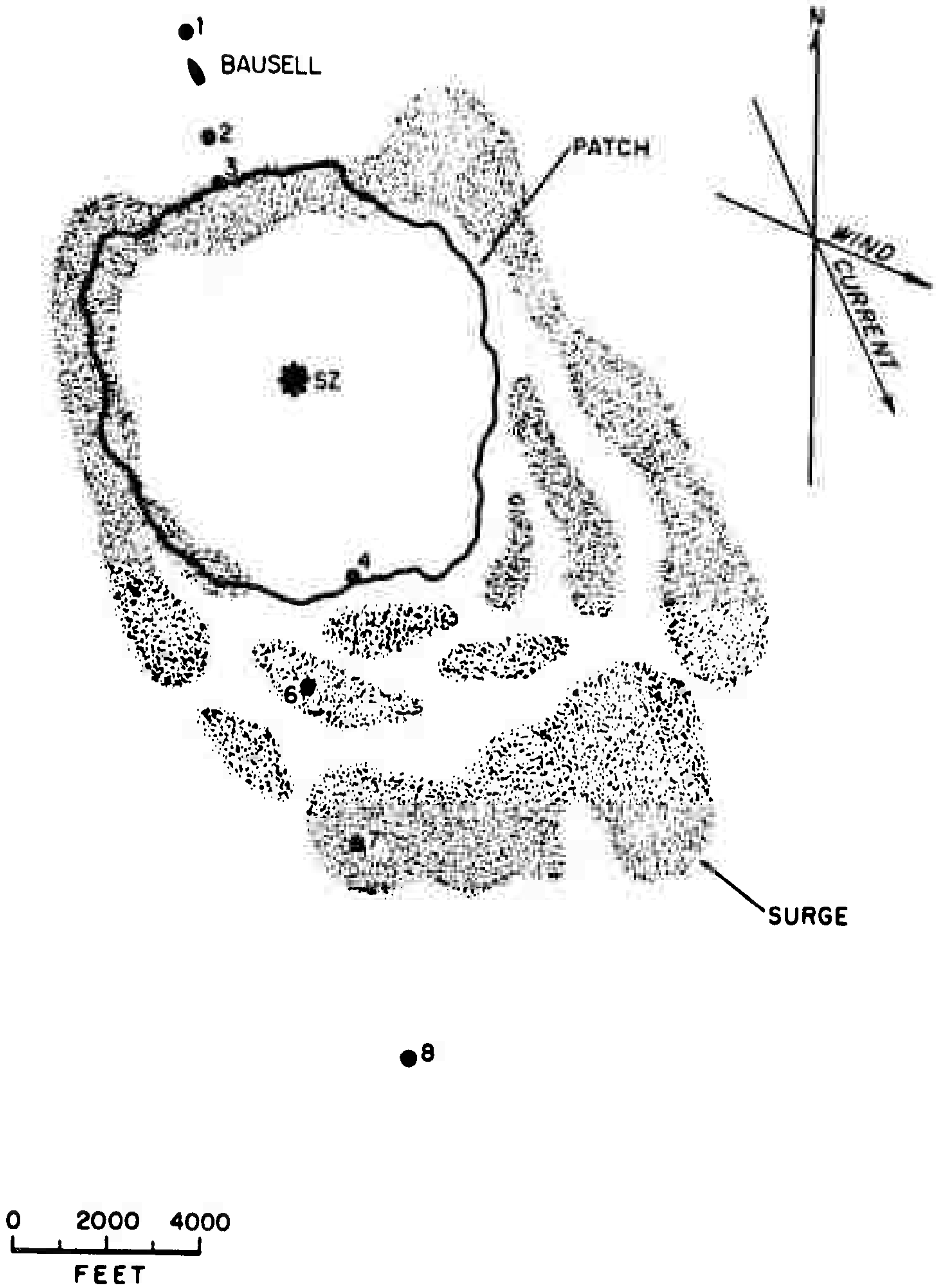

Figure 3.7 Approximate base surge and water patch configuration at H + 4 minutes.

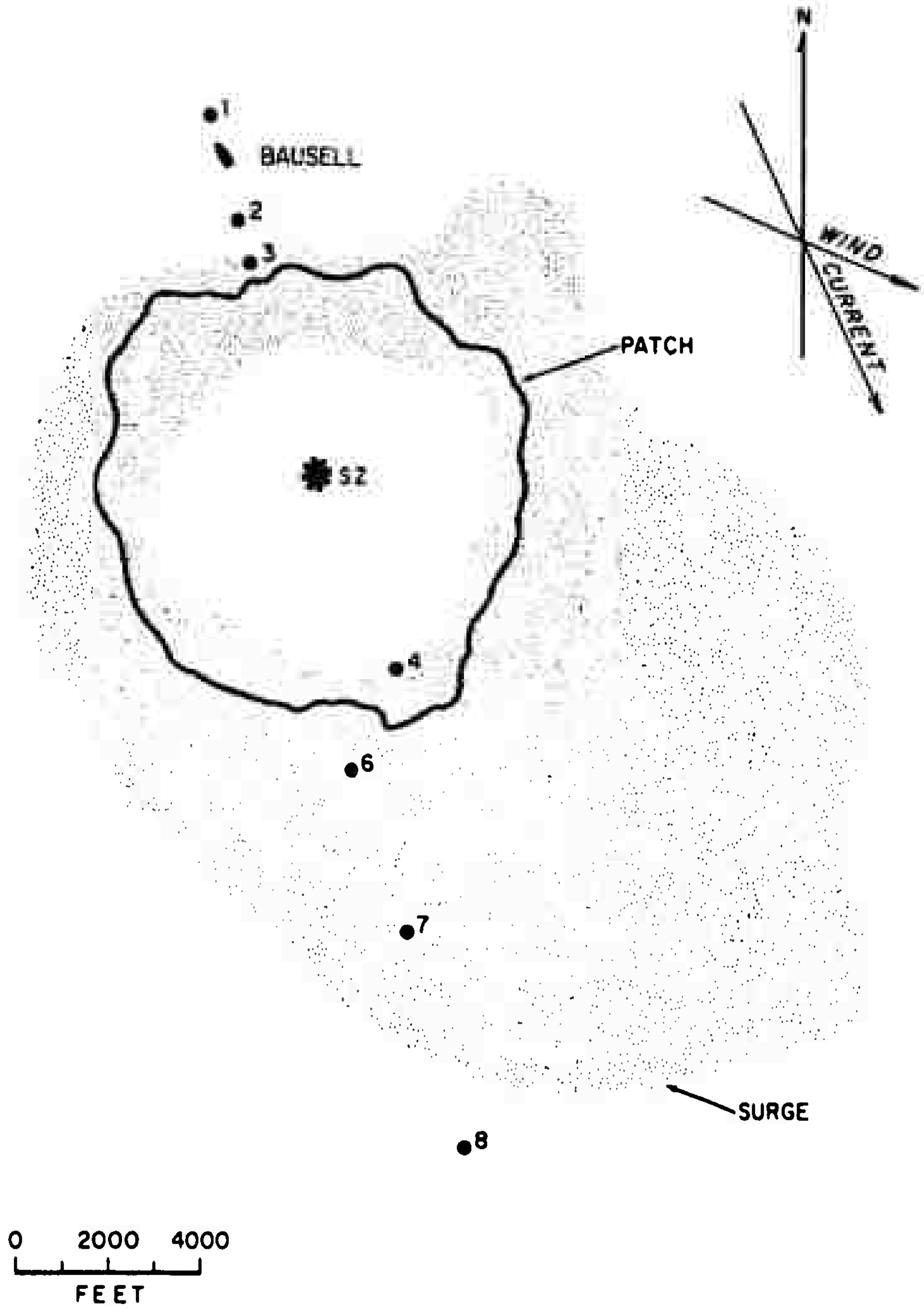

Figure 3.8 Approximate base surge envelope and water patch at H ≠ 5 minutes.

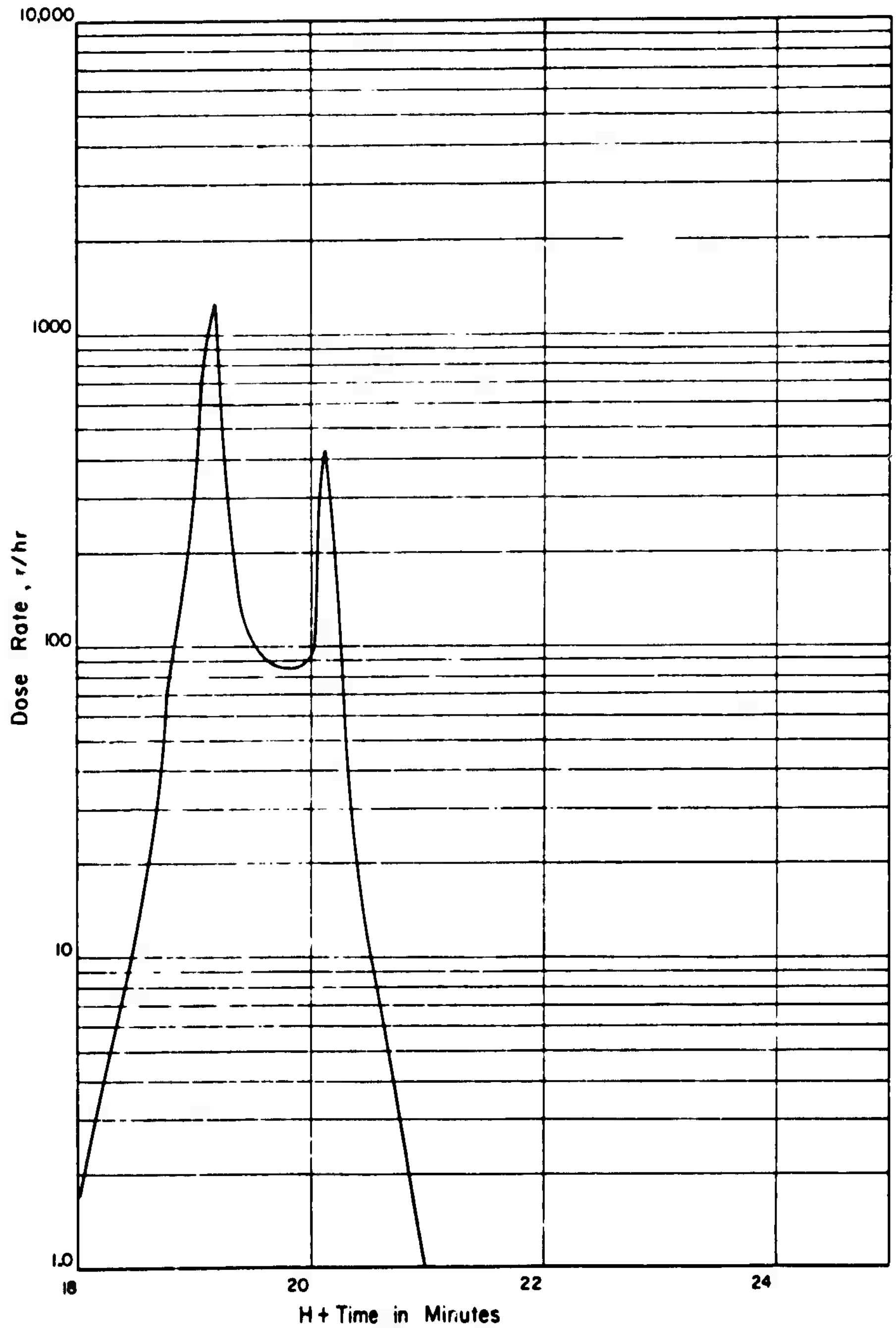

Figure 3.9 Dose rates versus time for first USS Sioux entry into patch.

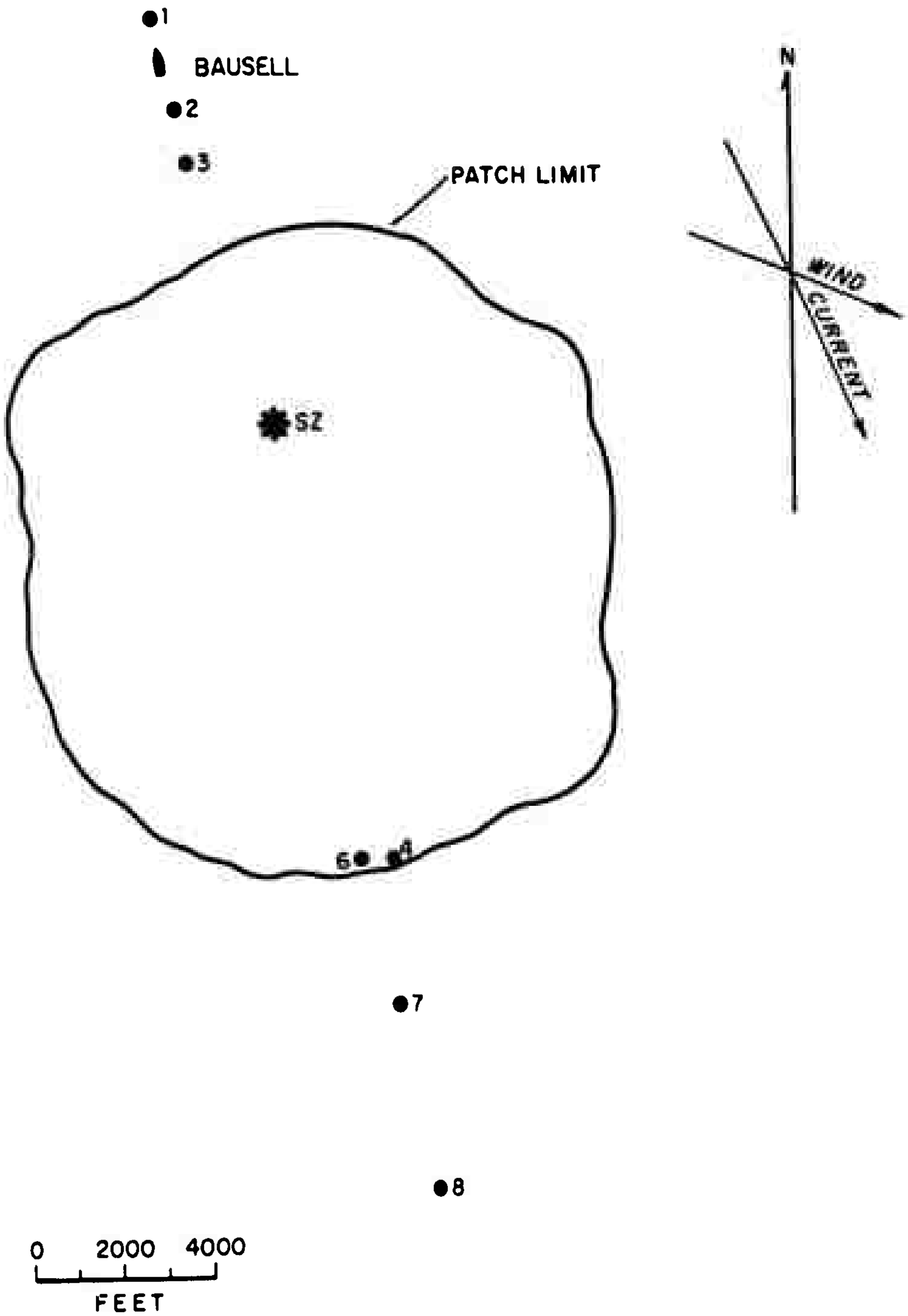

Figure 3.10 Water patch at H + 56 minutes.

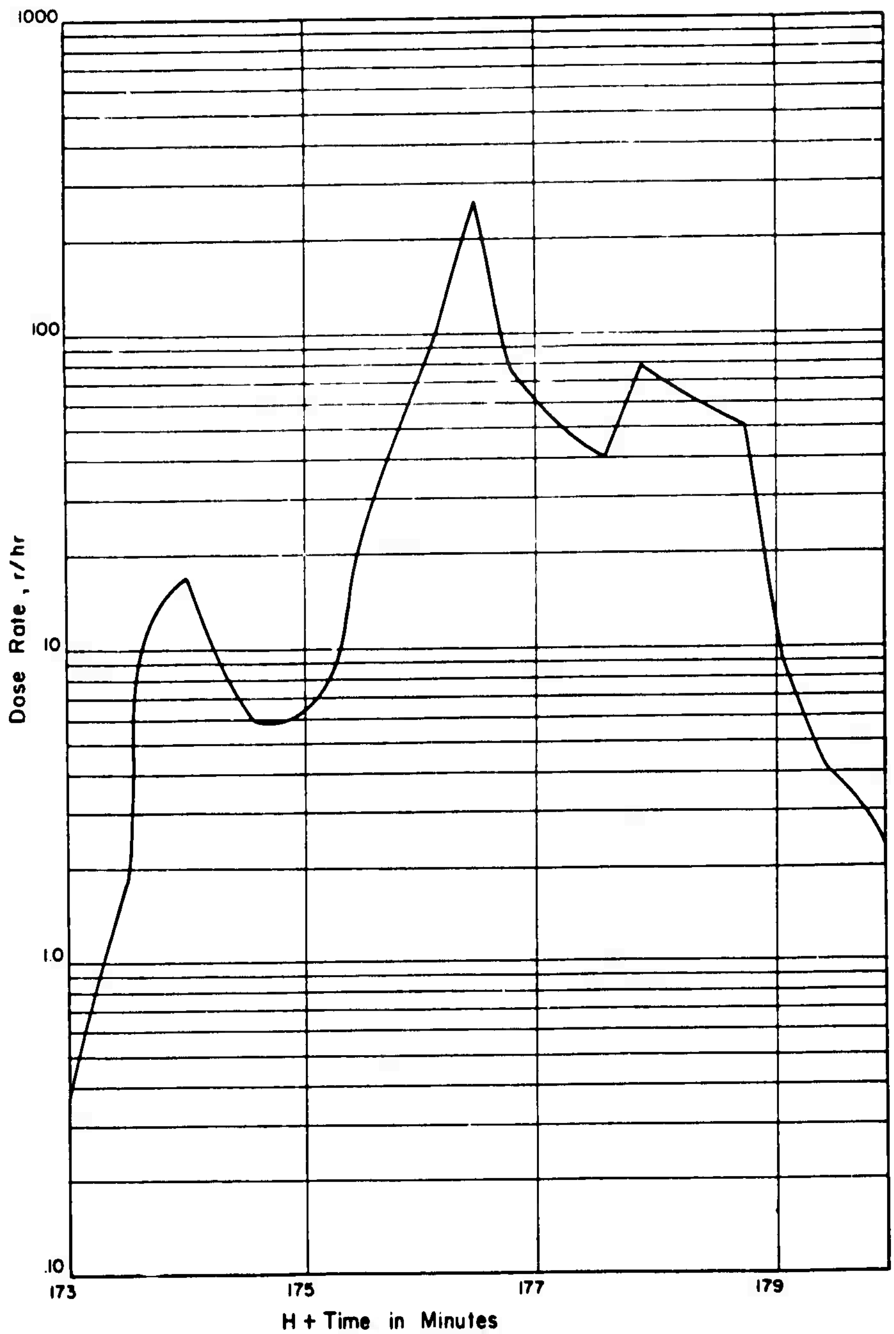

Figure 3.11 Dose rates versus time for second USS Sioux entry into patch.

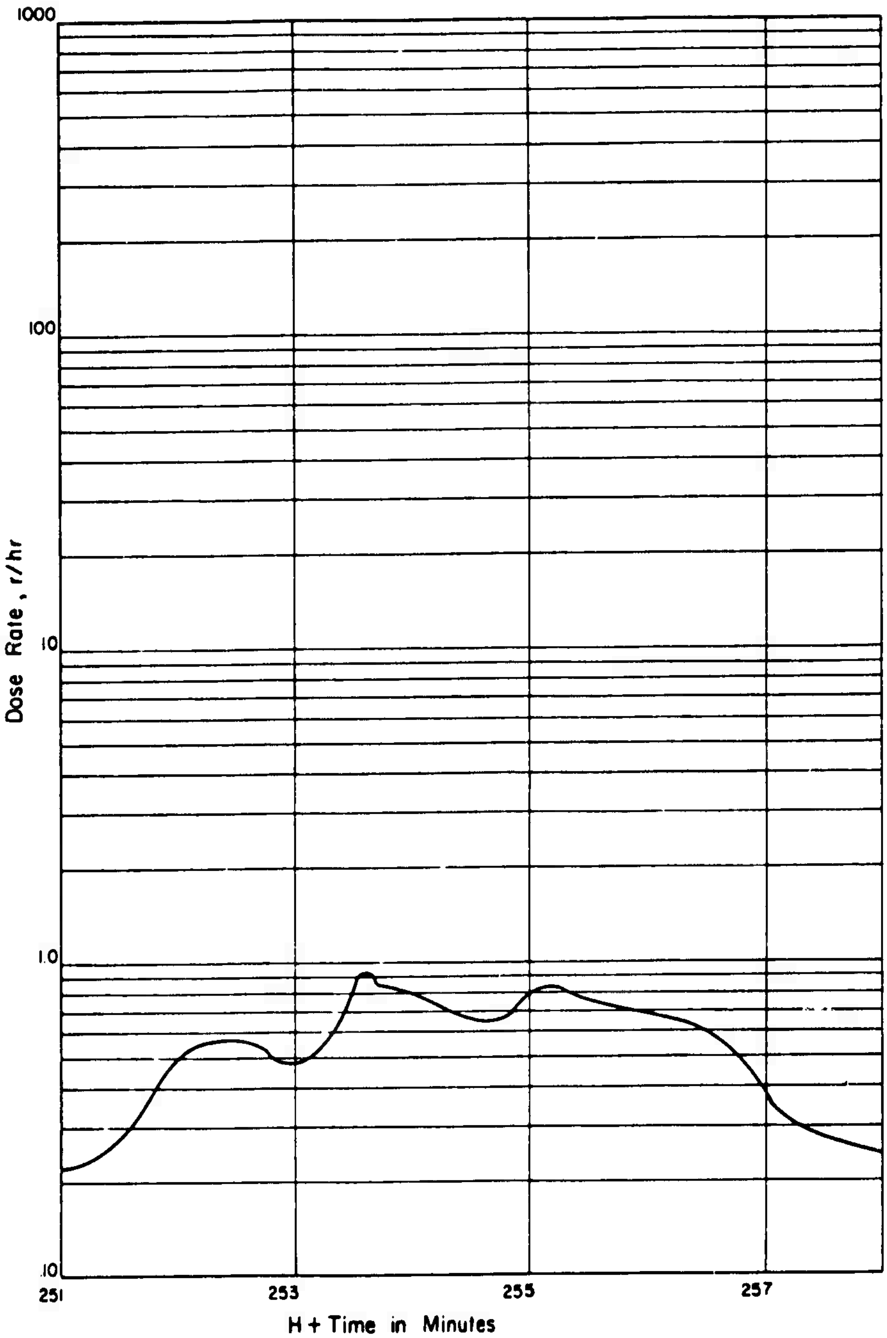

Figure 3.12 Dose rates versus time for third USS Sioux entry into patch.

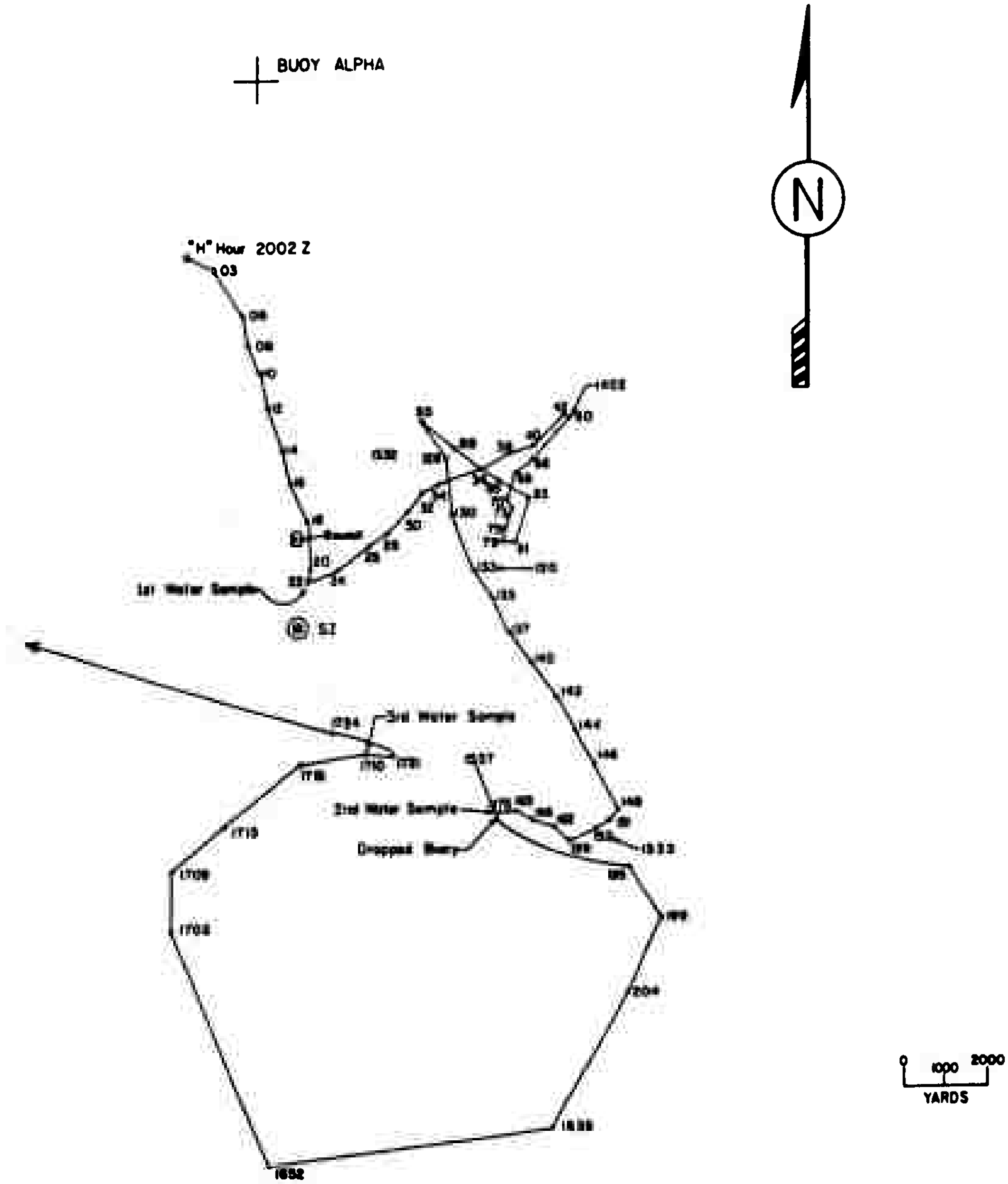

Figure 3.13 USS Sioux track in the radioactive patch.

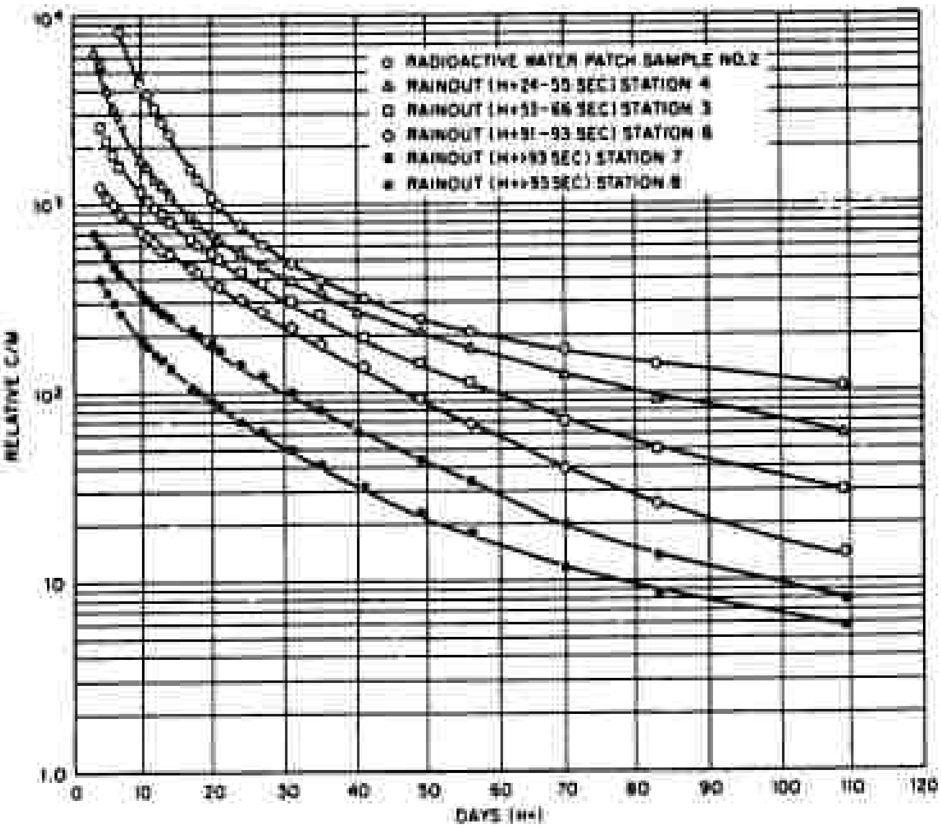

Figure 3.14 Deep well counter decay curves.

Page 68 Deleted.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Because of the operational conditions (detailed in Chapter 2), a comprehensive description of the event could not be made. The low station density and the skewed nature of the array markedly diminished the significance of the data obtained, in spite of its proven validity. Nevertheless, there was sufficient continuity in the data to form the composite picture of the event from the radiological viewpoint (given in Chapter 3), as well as several general conclusions arising from that picture. The validity of the radiological picture and the conclusions drawn from it are, however, strictly true only for the ASROC weapon detonated at the same depth and under the same site conditions that existed during the test. This is particularly true with regard to the surface wind conditions and the water depth. The presence of shallow water or a different surface wind condition would substantially alter the picture of the event as presented in this report. Any extension of this data to conditions other than those which existed for this test should be performed with special care and the best possible insight into the effects that the new conditions will have on the outcome of the event.

4.1 CONCLUSIONS

It is clear from the gamma records of those stations within the base surge that, at least for the first 30 minutes, it represented a tactical hazard for surface ships entering it. The potential of the hazard was further heightened, because after the first 10 minutes, the surge cloud limits were virtually invisible. By H + 20 minutes, its most dense portions were vague images, practically invisible. There were still gamma fields at the edge of the surge in excess of 100 r/hr, indicating that the base surge cloud was still a strong source of gamma radiation at locations within its limits. The only significant gamma dose contribution from the base surge, however, was confined to the transit dose. The contribution by surge-deposited contamination to the total dose at station locations within the surge appeared to be negligible.

For purposes of establishing radiologically safe delivery standoff distances, the extreme envelope of the base surge must be considered because of the unpredictable local variations in the surge contours. For this test the envelope extended about 6,500 feet upwind, 7,500 feet crosswind, and 14,000 feet downwind from the surface zero by H ≁ 5 minutes, at which time, having lost most of its energy of motion, it became windborne. Since it became invisible through evaporation shortly after that time, its location could be defined at later times only by assuming its progress was downwind at surface wind speed.

The extent of radionuclide fractionation in the rainfall from the base surge depended upon the length of time the droplets spent in the cloud before rainout. The radionuclides which did fractionate were those generally found in the radionuclide decay chains containing rare gas members having half-lives greater than about 10 seconds.

The dose rate levels within the contaminated water patch were higher and more presistent than had been indicated by all preshot estimates. Visible evidence of the patch either from the air or from a surface vessel was not a dependable guide to the location or extent of the patch for more than the first 30 minutes. The patch was still highly radioactive at that time as shown by the 1,000 r/hr gamma field at the very edge at H ≁ 20 minutes and the H ≁ 1 hour dose rate of 6,000 r/hr of station 6. There was strong evidence that the gamma field of the patch was not uniform, particularly at later times. The source of the radiation within the water patch could not be identified. Whether it arose from the foam, the surface water, or from highly contaminated water that had risen to the surface through upwelling caused by the detonation-induced turbulence of the water will have to await solution from future study and additional data.

From the experience of the USS Sioux entries into and later transits of the water patch, and the lack of significant gamma sources the following day within those salt water systems operated during that time, it was concluded that 24 hours of normal steaming in clear water was sufficiently effective decontamination of those systems to preclude having to take subsequent special decontamination procedures. Also, in the absence of any patch water on deck, firehosing of the weather deck proved an effective decontamination procedure for whatever small amount of contamination deposited by the aerosol above the patch during the H ≁ 20 minute entry.

Aside from its gamma field, the patch water was found to contain an alpha emitter (Pu^{239}) in relatively large quantities. In view of the very long half-life of this material, and the biological hazard associated with mere trace amounts, if ingested, it is advisable to consider securing all sanitary salt water systems and all other salt water systems not essential to the mobility of a vessel entering the patch.

The total gamma dose experienced by the Bausell originated initially from plume shine and finally from shine from the surge cloud. The surge never reached the vessel. The shape of the dose rate vs. time curves for the weather deck locations, aside from the dose rate levels, was almost identical to those of the coracle locations both upwind and downwind from the vessel. The dose rates and total dose also corresponded closely, with the distances from surface zero taken into consideration. Apparently, there was no significant shielding afforded the weather deck locations by the structure of the ship. The interior locations, however, showed a marked reduction in total dose as compared to the open deck. This reduction was as high as a factor of 100 for the locations well within the interior. Generally, the amount of reduction appeared to be in direct proportion to the amount of ship's structure between the detector location and the gamma source, the base surge in this case. It should be emphasized that over 90 percent of the total dose was delivered to all the locations on the target vessel within the first 10 minutes after detonation and that since the amount of shielding afforded by any medium is a function of energy spectrum and geometry of the source, the shielding observed in this case was strictly applicable only during this early time, and to the existing geometry. It might not be applicable, for example, at later time in the patch.

The yield of the weapon as independently determined from radiochemical analysis of contaminated water patch samples and quantitative knowledge of the device's original constitutents was

4.2 RECOMMENDATIONS

There is insufficient information available to be able to predict with certainty the average dose rate with time for the contaminated water patch. Before it is possible to establish the earliest safe times of entry, additional data is required. Ideally, this information should include detailed dose contours with respect to time, selective radiochemical analysis and decays of a large number of water and foam samples, and in situ energy spectral analysis of the gamma field and the samples. All of the above information should be obtained at various depths as well as at the surface. The most important data would be that of the dose rates contours. This could best be obtained by use of a properly instrumented low-flying aircraft operated in conjunction with surface GITR stations serving as the calibration datum for the aerial survey. The feasibility of this type of water patch survey has already been proven by the results of Project 2.2 (Reference 12).

Appendix

RECORDS

This appendix contains the gamma dose rates versus time records (Figures A.1 through A.19) for project floating (coracle) and shipboard (USS Bausell) stations.

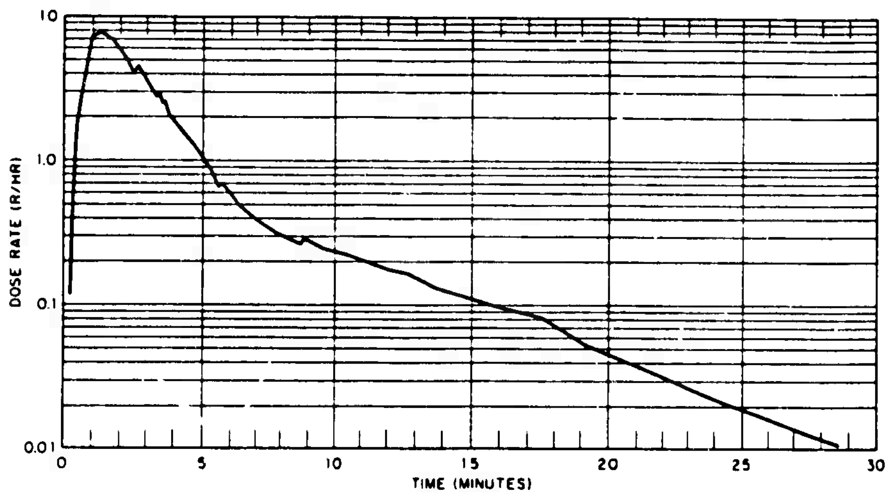

Figure A.1 Gamma dose rate versus time (0–30 min) for Station 1.

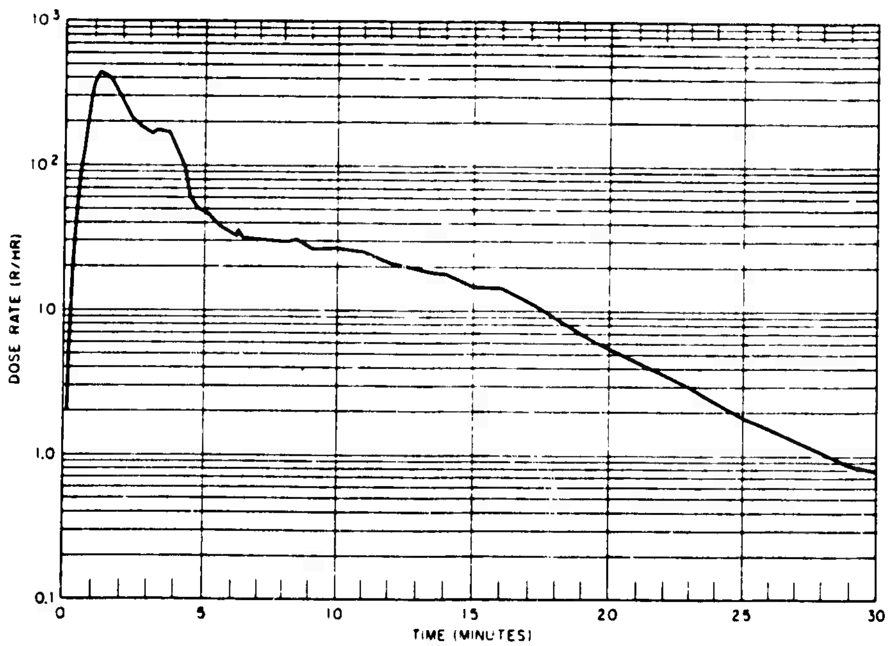

Figure A.2 Gamma dose rate versus time (0–30 min) for Station 2.

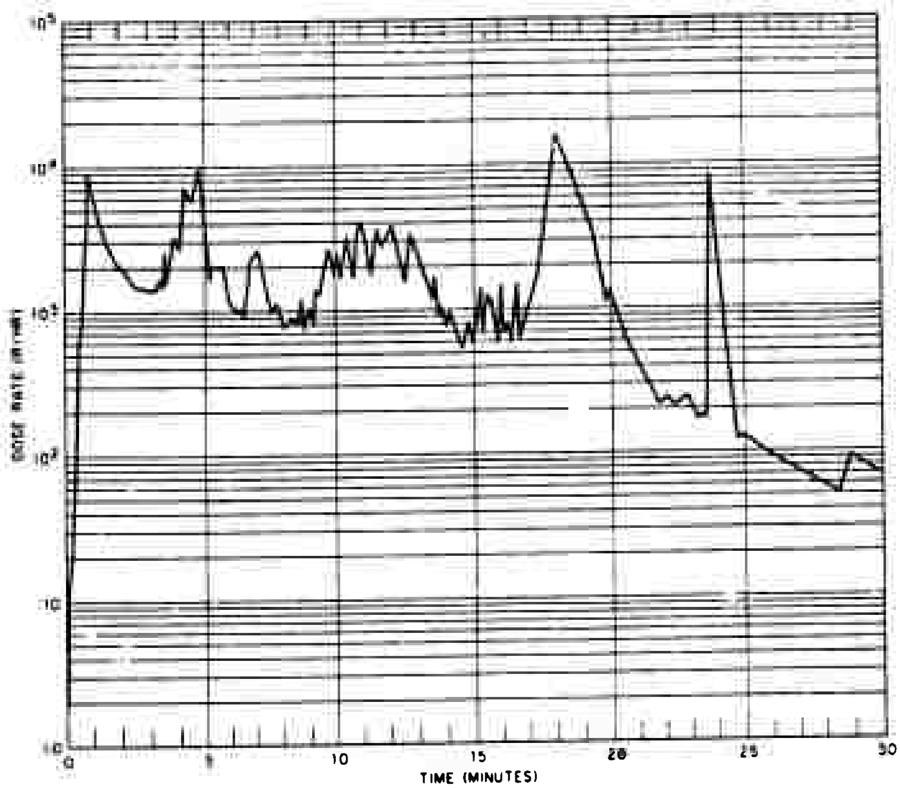

Figure A.3 Gamma dose rate versus time (0–30 min) for Station 3.

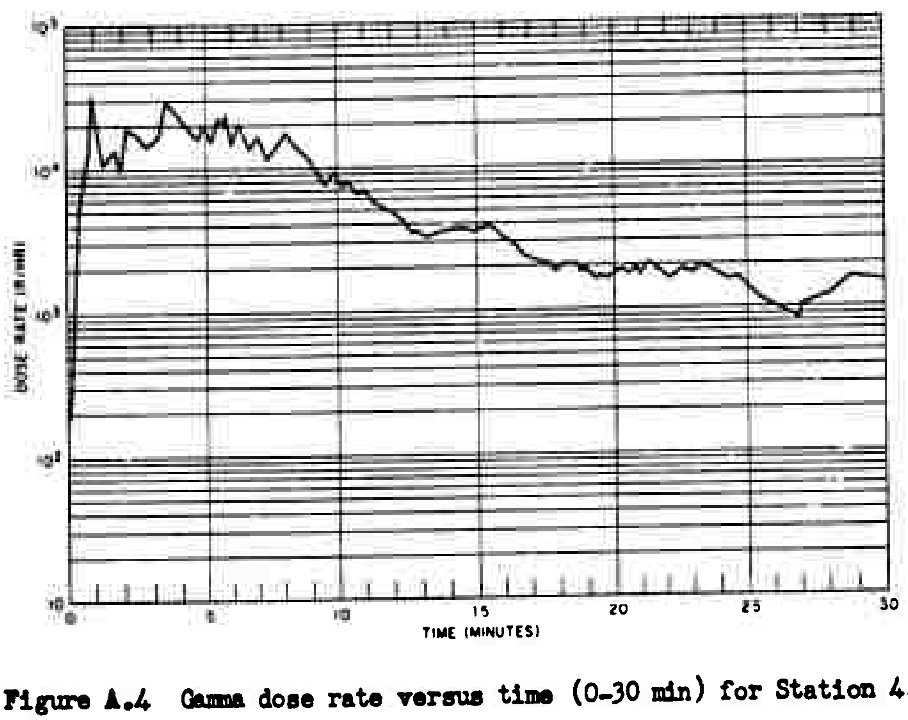

Figure A.4 Gamma dose rate versus time (0–30 min) for Station 4.

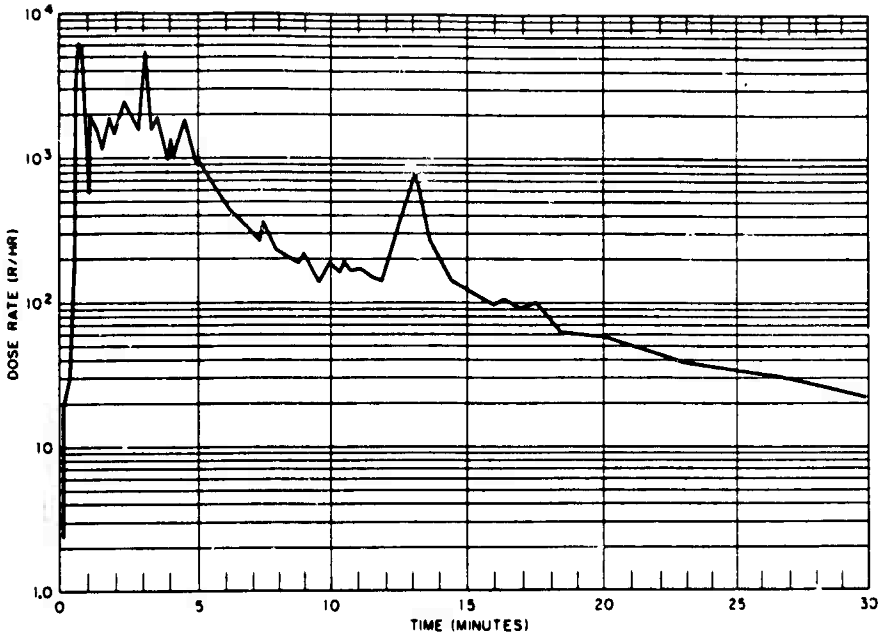

Figure A.5 Gamma dose rate versus time (0-30 min) for Station 5.

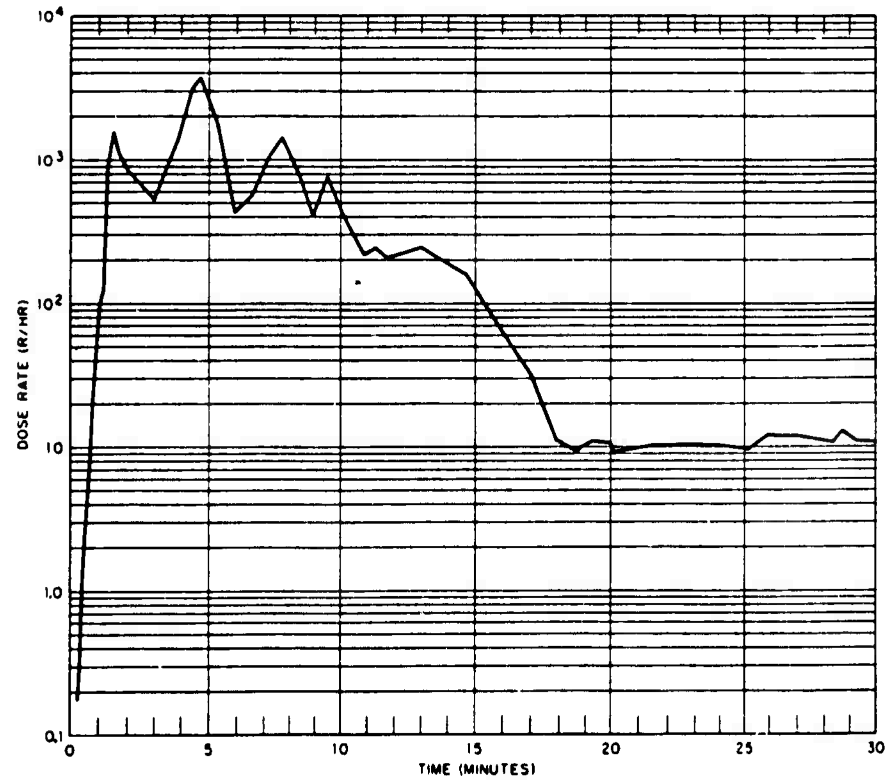

Figure A.6 Gamma dose rate versus time (0-30 min) for Station 6.

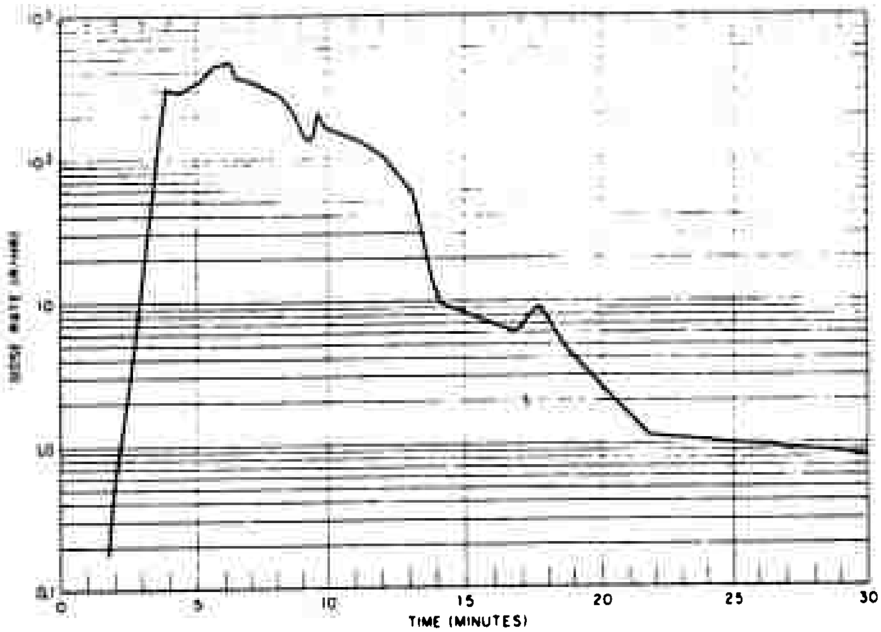

Figure A.7 Gamma dose rate versus time (0-30 min) for Station 7.

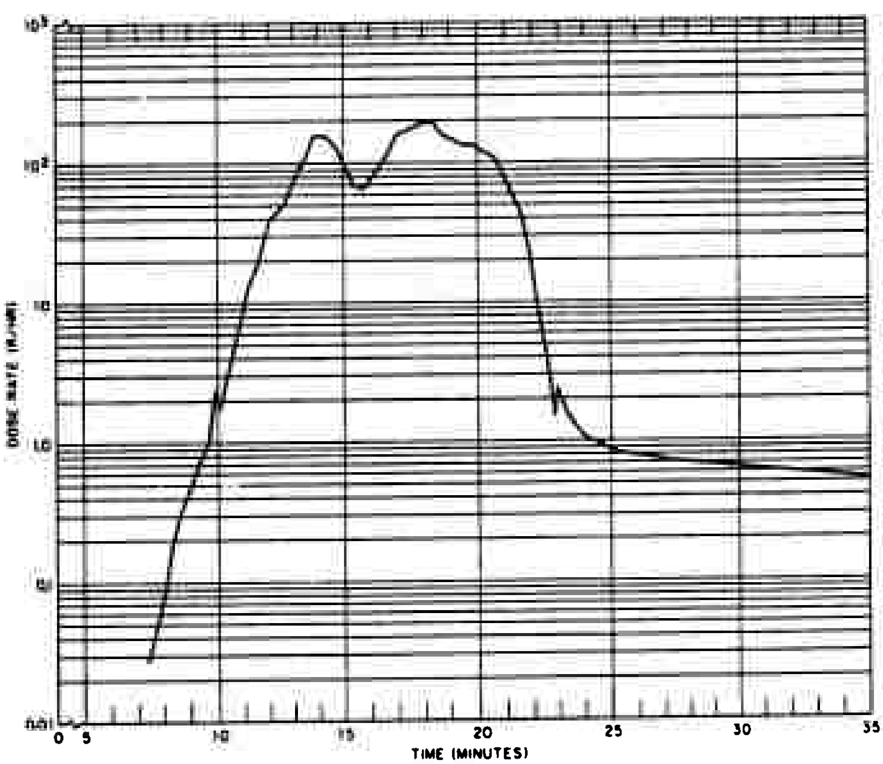

Figure A.8 Gamma dose rate versus time (0-30 min) for Station 8.

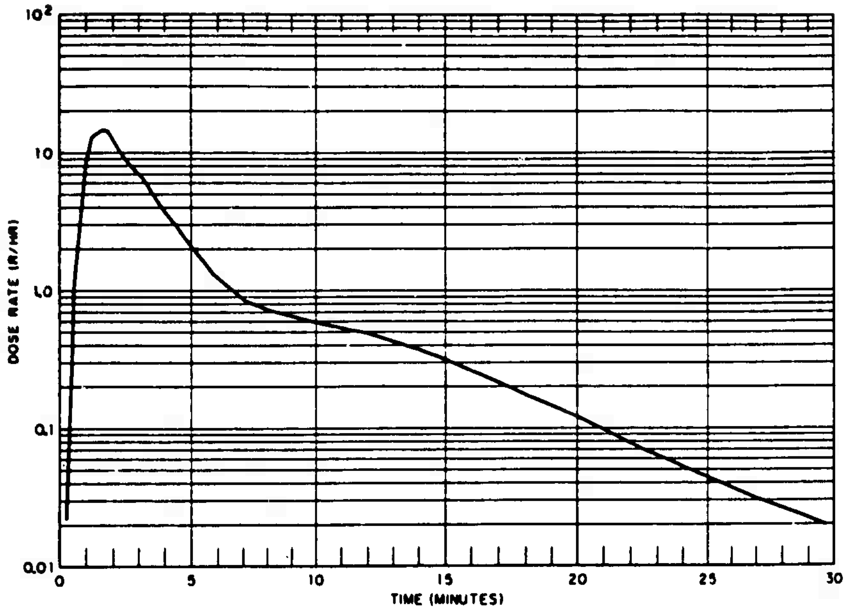

Figure A.9 Gamma dose rate versus time (0–30 min) for shipboard location 1 (Forecastle).

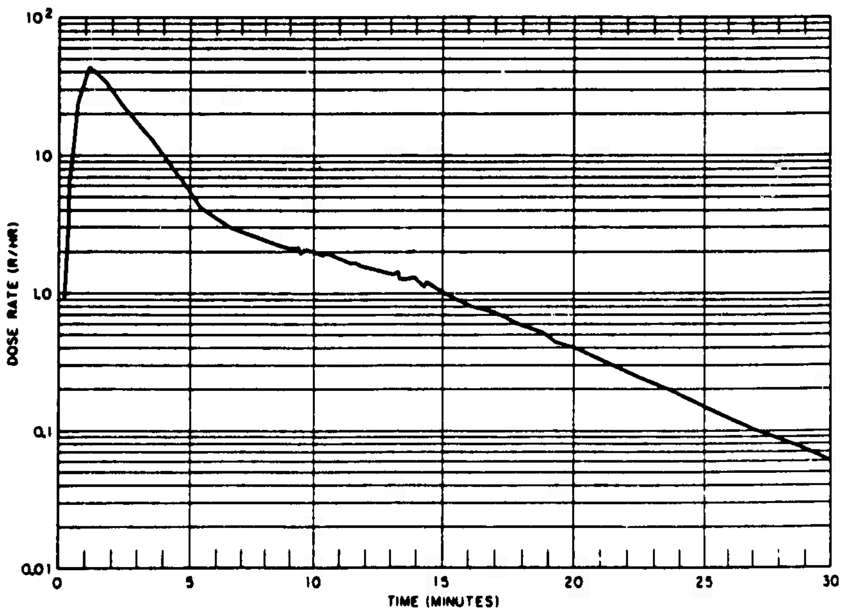

Figure A.10 Gamma dose rate versus time (0–30 min) for shipboard location 4 (Fantail).

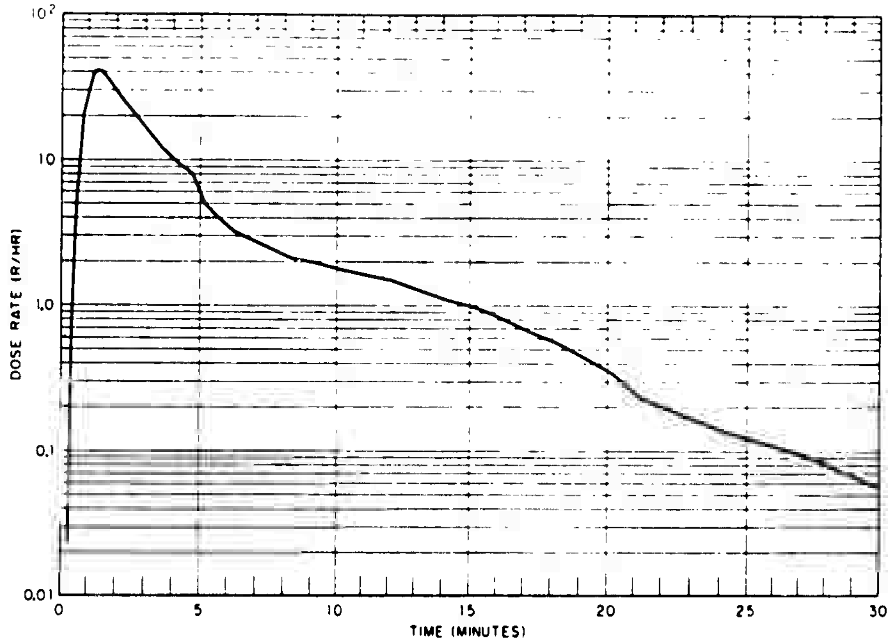

Figure A.11 Gamma dose rate versus time (0-30 min) for shipboard location 5 (Flight deck).

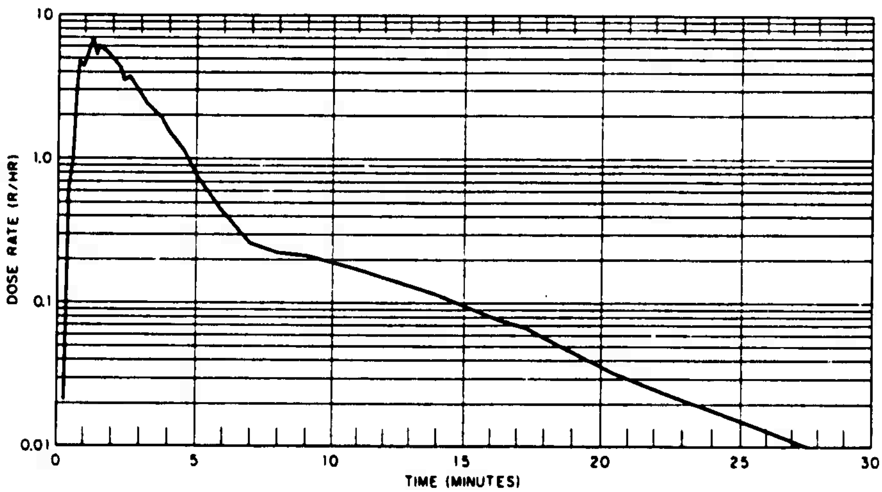

Figure A.12 Gamma dose rate versus time (0-30 min) for shipboard location 7 (Aft crew's quarters).

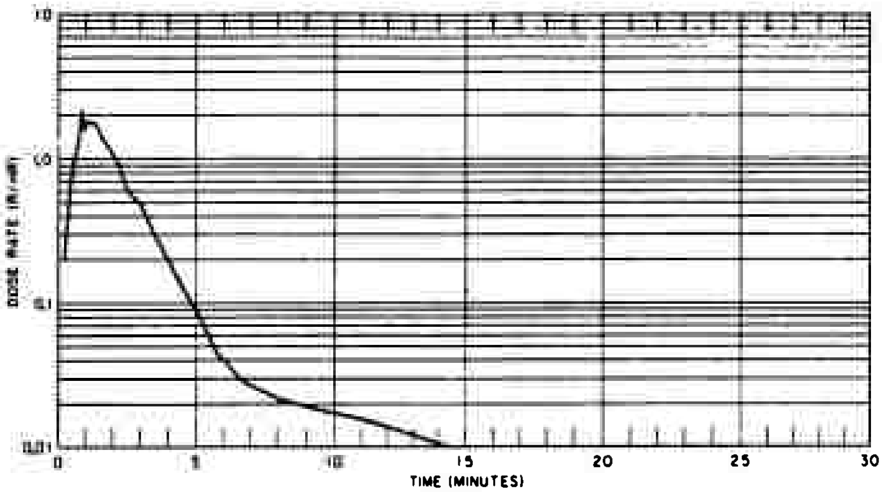

Figure A.13 Gamma dose rate versus time (0-30 min) for shipboard location 8 (Forward crew's quarters).

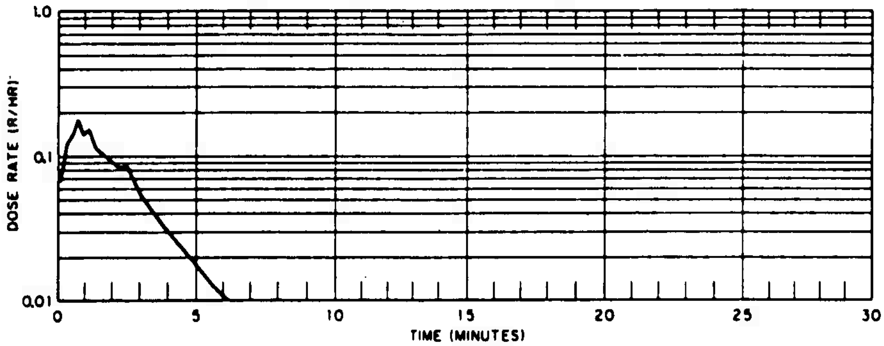

Figure A.14 Gamma dose rate versus time (0-30 min) for shipboard location 9 (5" Ammo handling room).

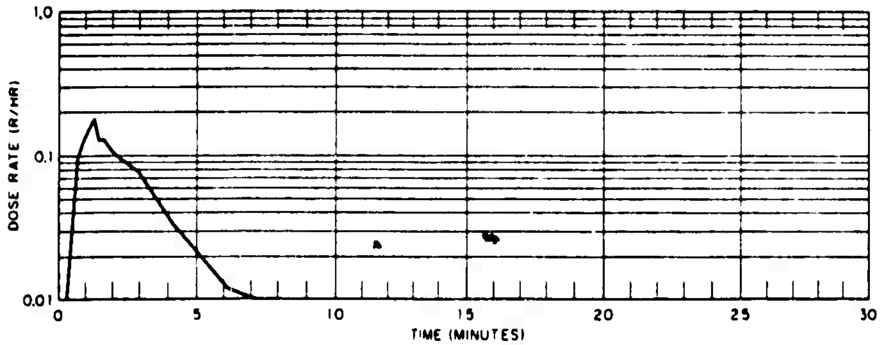

Figure A.15 Gamma dose rate versus time (0-30 min) for shipboard location 10 (Forward engine room).

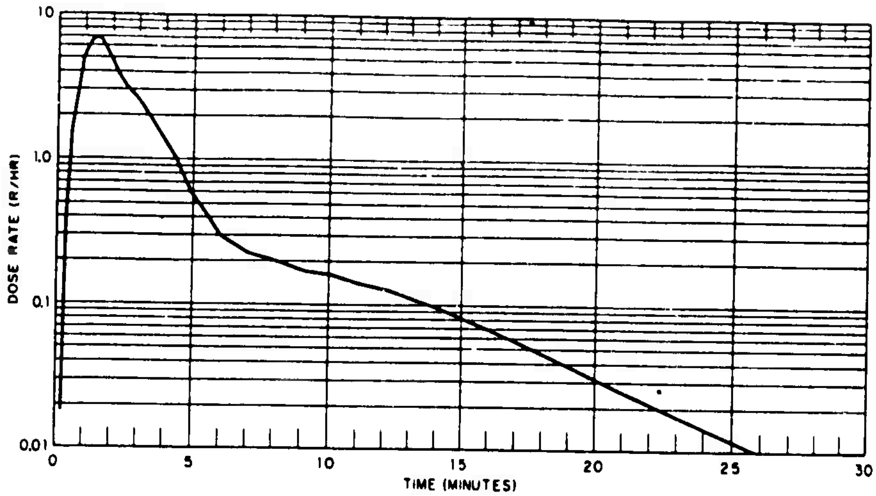

Figure A.16 Gamma dose rate versus time (0–30 min) for shipboard location 11 (5" gun turret, Mount 52).

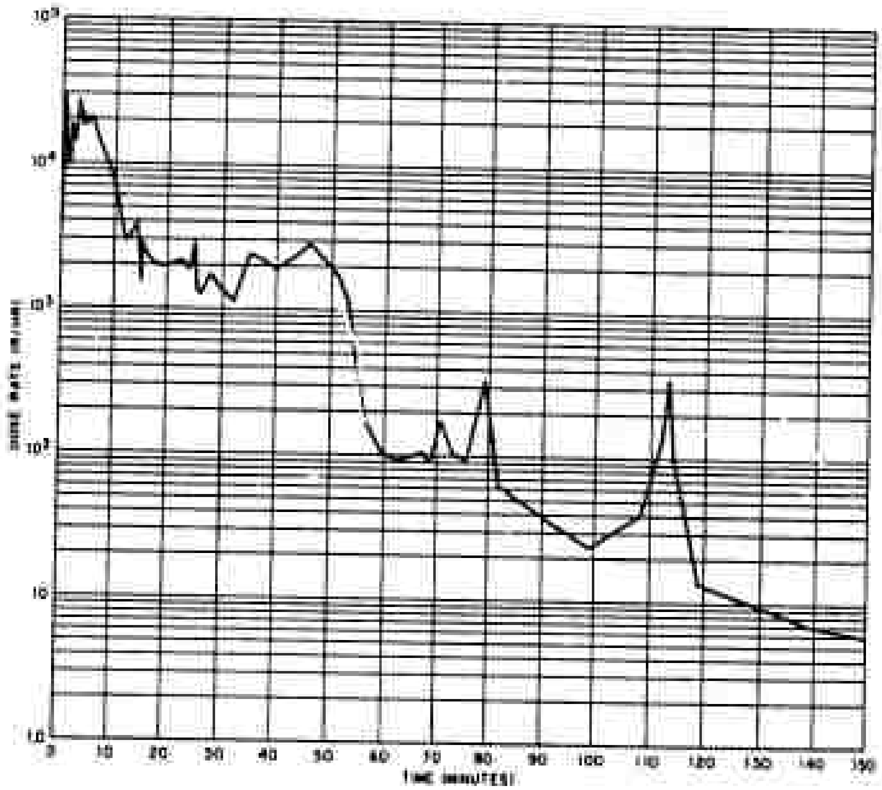

Figure A.17 Gamma dose rate versus time (0–2½ hr) for Station 4.

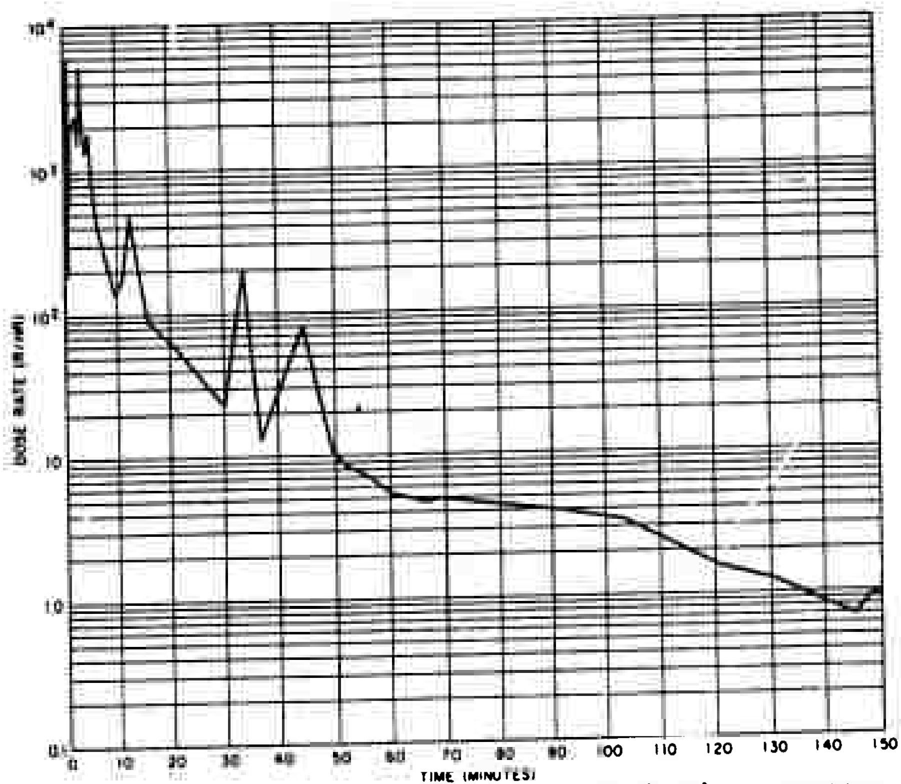

Figure A.18 Gamma dose rate versus time (0–2½ hr) for Station 5.

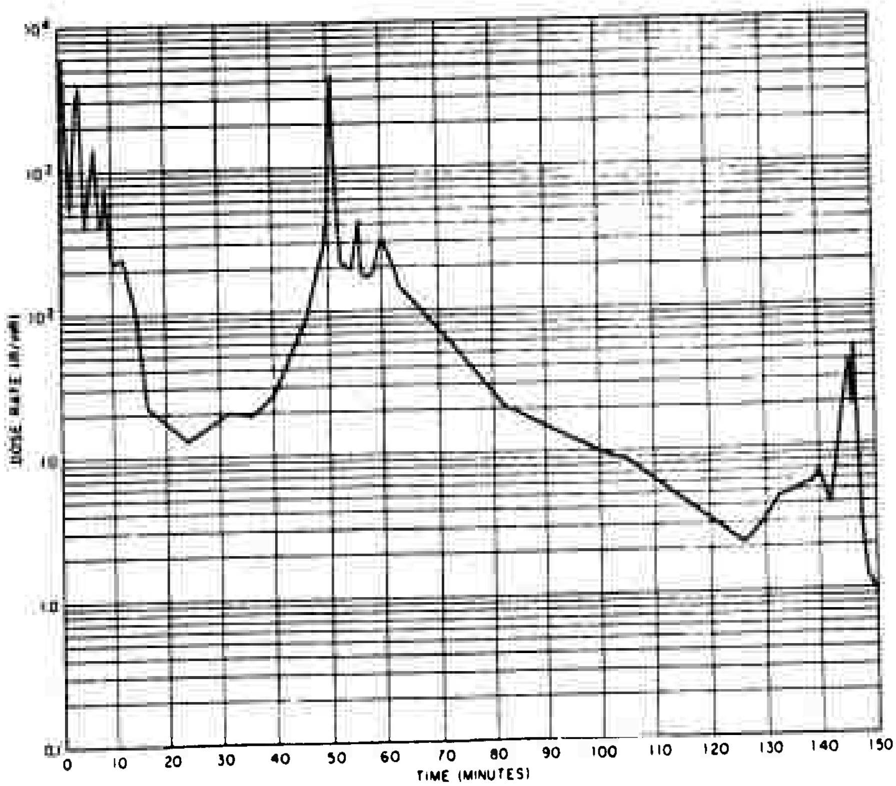

Figure A.19 Gamma dose rate versus time (0–2½ hr) for Station 6.

REFERENCES

1. Report of the Technical Director, Operation Crossroads; Report No. XRD-209, dated May 1947; Secret Restricted Data.

2. N. E. Ballou; "Radiochemical and Physical Chemical Properties of Products of a Deep Underwater Nuclear Detonation"; Project 2.3, Operation Wigwam, WT-1011, 17 April 1957; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; Secret Restricted Data.

3. E. C. Evans III, and T. H. Shirasawa; "Characteristics of the Radioactive Cloud from Underwater Burst (U)"; Project 2.3, Operation Hardtack, WT-1621, 15 January 1962; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; Confidential Formerly Restricted Data.

4. J. C. Ulberg; "Droplet Coalescence Model for Base Surge Aerosols"; USNRDL TR; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; to be published.

5. R. R. Soule, W. W. Perkins, and E. A. Schuert; "An Investigation of the Radiological Effects from Underwater Nuclear Explosions using 10,000-Pound High-Explosive Charges as Models (U)"; Hydra Program—Hydra IIA Interim Report, 23 August 1962; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; Confidential.

6. D. P. Schultze, C. J. Cillay; "Naval Ship Standoff Ranges from Underwater Nuclear Detonations (U)"; USNRDL TR; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; to be published; Confidential Formerly Restricted Data.

7. I. O. Heubsch; "A Radiological Model for Computing Base Surge Dose-Rate Histories for Underwater Bursts"; USNRDL TR; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; to be published.

8. T. Shirasawa; "The Initial Dimension and Instensity of the Oceanic-Radioactivity Resulting from an Underwater Explosion"; NRDL/AEC Sword Fish Project; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California.

9. Memorandum, Acting Head Nuclear Chemical Branch to Associate Scientific Director, NRDL, 27 June 1962; "Preliminary Yield Estimate of ASROC Weapon from Shot Sword Fish of Operation Domonic", 0022947; Secret Restricted Data.

10. C. F. Miller and P. Loeb; "Ionization Rate and Photon Pulse Decay of Fission Products from Slow-Neutron Fission of U^{235}"; USNRDL TR-247, August 1958; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; Unclassified.

11. H. A. Zagorites and others; "NRDL Gamma-Intensity-Time Recorder, Model 103"; USNRDL TR; U.S. Naval Radiological Defense Laboratory, San Francisco 24, California; to be published.

12. "Aerial Survey of the Surface Radioactivity Remaining after an Underwater Nuclear Detonation"; E. J. Wesley, R. Cole, M. A. Olsen; W.F. Joseph; USNRDL TR in Publication February 1963; Confidential.